Glencoe Science

PHYSICS
Principles and Problems

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Chapters 21–25 Resources

AUTHORS

Zitzewitz ■ Elliott ■ Haase ■ Harper ■ Herzog
Nelson ■ Nelson ■ Schuler ■ Zorn

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PHYSICS
Principles and Problems

Student Edition

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Contents

Chapters 21–25 Resources

To the Teacher

This book contains resources that support five Student Edition chapters of *Physics: Principles and Problems.* The worksheets and activities have been developed to help you teach these chapters more effectively. You will find in chapter order:

REPRODUCIBLE PAGES

HANDS-ON ACTIVITIES

Mini Lab and Physics Lab Worksheets: These worksheets are expanded versions of the Mini Labs and Physics Labs that appear in the five Student Edition chapters supported in this book. All materials lists, procedures, and questions are repeated so that students can complete a lab in most cases without having a textbook on the lab table. Data tables are enlarged so they can be used to easily record data, and all lab questions are reprinted with lines on which students can write their answers. For student safety, all appropriate safety symbols and caution statements have been reproduced on these pages. Answer pages for each Mini Lab and Physics Lab Worksheet are included in the Teacher Guide and Answers section at the back of this book.

EXTENSION AND INTERVENTION

Study Guide: These pages help your students learn physics vocabulary and concepts. Study Guide worksheets typically consist of six pages of questions and exercises for each of the five Student Edition chapters supported in this book. Items are presented in a variety of objective formats: matching, true/false, interpreting diagrams and data, multiple choice, short-answer questions, and so on. The first Study Guide worksheet for each chapter reviews vocabulary. Subsequent worksheets closely follow the organization of the textbook, providing review items for each textbook section and references to specific content.

Students will find the Study Guide worksheets helpful for previewing or reviewing chapter material. As a preview, the worksheets help students focus on the concepts at the time you assign the reading. Students can complete each Study Guide section after reading the corresponding textbook section. Some students will have more success completing the sheets in smaller chunks. For this reason, the question sets on the Study Guide pages are referenced to specific readings in the textbook. When complete, these worksheets will prove to be an excellent review instrument. Answers to the Study Guide pages are included in the Teacher Guide and Answers section at the back of this book.

Reinforcement: These pages provide opportunities that complete your teaching cycle and benefit all your students. Reinforcement masters are especially helpful for students who require additional instruction in order to understand certain concepts. A Reinforcement master is provided for each of the five Student Edition chapters supported in this book. Answers to these pages are included in the Teacher Guide and Answers section at the back of this book.

Enrichment: These activities offer students the chance to apply physics concepts to new situations. Students explore high-interest topics in a variety of formats. Some of the masters are hands-on activities. An Enrichment master is provided for each of the five Student Edition chapters supported in this book. Answers to these pages are included in the Teacher Guide and Answers section at the back of this book.

TRANSPARENCY ACTIVITIES

Teaching Transparency Masters and Activities: These transparencies relate to major concepts that will benefit from an extra visual learning aid. Most of the transparencies contain art or photos that extend the concepts put forth by those in the textbook. Others contain art or photos directly from the Student Edition. There are 120 Teaching Transparencies. The ones that support these five Student Edition chapters are provided here as black-and-white masters accompanied by worksheets that review the concepts presented in the transparencies. Teaching Tips for some transparencies and answers to all worksheet questions are provided in the Teacher Guide and Answers section at the back of this book.

ASSESSMENT

Section Quiz: The Section Quiz page consists of questions or problems that focus on key content from one section of the Student Edition. Each quiz typically includes conceptual items that require a written response or explanation and items that require problem-solving skills or mathematical calculations, where applicable. The Section Quiz offers representative practice items that allow you to monitor your students' understanding of the textbook. Answers to each Section Quiz are provided in the Teacher Guide and Answers section at the back of this book.

Chapter Assessment: The Chapter Assessment pages provide materials to evaluate your students' understanding of concepts and content from the five Student Edition chapters supported in this book. Each test consists of six pages of material, which is divided into three sections.

- Understanding Physics Concepts requires students to demonstrate their knowledge of vocabulary and other basic information presented in the chapter. They are assessed through a variety of question types, including matching, modified true/false, short answer/fill-in, and multiple choice.

- Thinking Critically requires students to use higher-order learning skills. Students will need to interpret data and discover relationships presented in graphs and tables. Other questions may require them to apply their understanding of concepts to solve problems, compare or contrast situations, and make inferences or predictions.

- Applying Physics Knowledge consists of items that assess students' ability to extend their learning to new situations. Assessment is done qualitatively through short-answer questions, and quantitatively through problems. The questions and problems in this section are more difficult than those presented earlier and generally require more calculations as well as a deeper comprehension of chapter concepts.

TEACHER GUIDE AND ANSWERS

Answers or possible answers to all worksheet questions and activities can be found in order of appearance at the back of this book. Criteria for acceptable answers are found where appropriate.

Electric Fields

CHAPTER
21 — Mini Lab Worksheet

Electric Fields

Tie a pith ball on the end of a 20-cm nylon thread and tie the other end to a plastic straw. Holding the straw horizontally, notice that the ball hangs straight down. Now rub a piece of wool on a 30-cm × 30-cm square of plastic foam to charge both objects. Stand the foam vertically. Hold the straw and touch the pith ball to the wool.

1. **Predict** what will happen when the ball is close to the foam.

2. **Test** your prediction by slowly bringing the hanging ball toward the charged plastic foam.

3. **Predict** the ball's behavior at different locations around the foam, and test your prediction.

4. **Observe** the angle of the thread as you move the pith ball to different regions around the foam.

Analyze and Conclude

5. **Explain,** in terms of the electric field, why the ball swings toward the charged plastic?

_____

_____

_____

6. **Compare** the angle of the thread at various points around the foam. Why did it change?

_____

_____

_____

7. **Infer** what the angle of the thread indicates about the strength and the direction of the electric field.

_____

_____

_____

CHAPTER
21 — Physics Lab Worksheet

Materials

- 9-V battery
- 9-V battery clip
- hook-up wires
- switch
- voltmeter
- 47-kΩ resistor
- stopwatch
- capacitors: 1000 μF, 500 μF, 240 μF
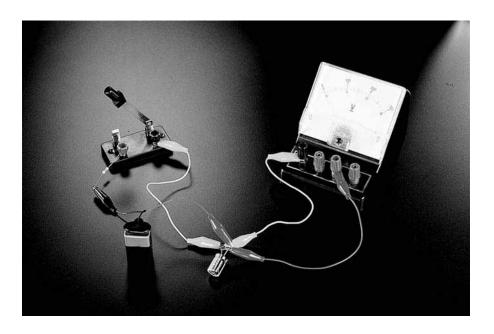
Charging of Capacitors

A capacitor is an electric device that is made from two conductors, or plates, that are separated by an insulator, and is designed to have a specific capacitance. The capacitance depends on the physical characteristics and geometric arrangement of the conductors and the insulator. In the circuit schematic, the capacitor appears to create an open circuit, even when the switch is in the closed position. However, because capacitors store charge, when the switch is closed, charge from the battery will move to the capacitor. The equal, but opposite charges on the two plates within the capacitor establishes a potential difference, or voltage. As charge is added to the capacitor, the electric potential difference increases. In this laboratory activity you will examine the charging of several different capacitors.

Question

How do the charging times of different capacitors vary with capacitance?

Objectives

- **Collect and organize** data on the rate of charge of different capacitors.
- **Compare and contrast** the rate of charging for different capacitances.
- **Make and use graphs** of potential difference versus time for several capacitors.

Data Table							
Time (s)	Voltage (V) on 1000 μF	Voltage (V) on 500 μF	Voltage (V) on 240 μF	Time (s)	Voltage (V) on 1000 μF	Voltage (V) on 500 μF	Voltage (V) on 240 μF
0				55			
5				60			
10				65			
15				70			
20				75			
25				80			
30				85			
35				90			
40				95			
45				100			
50				105			

Procedure

1. Before you begin, leave the switch open (off). Do not attach the battery at this time. *CAUTION: Be careful to avoid a short circuit, especially by permitting the leads from the battery clip to touch each other.* Connect the circuit, as illustrated. Do this by connecting either end of the resistor to one side of the switch. The resistor is used to reduce the charging of the capacitor to a measurable rate. Connect the other end of the resistor to the negative side of the 9-V battery clip. Inspect your 1000-μF capacitor to determine whether either end is marked with a negative sign, or an arrow with negative signs on it, that points to the lead that is to be connected to the negative side of the battery. Connect this negative lead to the other side of the switch. Attach the unconnected (positive) lead of the capacitor to the positive lead from the battery clip.

2. Connect the positive terminal of the voltmeter to the positive side of the capacitor and the negative terminal to the negative side of the capacitor. Compare your circuit to the figure to verify your connections. Attach the battery after your teacher has inspected the circuit.

3. Prepare a data table, having columns for time and potential difference on each of the three different capacitors.

4. One person should watch the time and another should record potential difference at the designated times. Close the switch and measure the voltage at 5-s intervals. Open the switch after you have collected data.

5. When you have completed the trial, take a short piece of wire and place it across both ends of the capacitor. This will cause the capacitor to discharge.

6. Replace the 1000-μF capacitor with a 500-μF capacitor. Repeat steps 4–5 and enter data into the appropriate columns of your data table for the 500-μF capacitor.

7. Replace the 500-μF capacitor with a 240-μF capacitor. Repeat steps 4–5 and enter data into the appropriate column of your data table for this last capacitor.

Analyze

1. **Observe and Infer** Does each capacitor charge to 9 V? Propose an explanation for the observed behavior.

   _____

   _____

   _____

   _____

2. **Make and Use Graphs** Prepare a graph that plots the time horizontally and the potential difference vertically. Make a separate labeled line for each capacitor.

Conclude and Apply

1. **Interpret Data** Does the voltage on the capacitor immediately jump to the battery's potential difference (9-V)? Explain the reason for the observed behavior.

   _____

   _____

   _____

2. **Infer** Does the larger capacitor require a longer time to become fully charged? Explain why or why not.

   _____

   _____

   _____

Going Further

1. The time for a capacitor to charge to the voltage of the battery depends upon its capacitance and the opposition to the flow of charge in the circuit. In this lab, the opposition to the flow of charge was controlled by the 47-kΩ resistor that was placed in the circuit. In circuits with a capacitor and resistance, such as in this activity, the time in seconds to charge the capacitor to 63.3 percent of the applied voltage is equal to the product of the capacitor and resistance. This is called the time constant. Therefore, $T = RC$, where T is in seconds, R is in ohms, and C is in microfarads. Calculate the time constant for each of the capacitors with the 47-kΩ resistor.

2. Compare your time constants to the values from your graph.

Real-World Physics

Explain Small, disposable, flash cameras, as well as regular electronic flash units, require time before the flash is ready to be used. A capacitor stores the energy for the flash. Explain what might be going on during the time you must wait to take your next picture.

_____

_____

_____

Physics nline

To find out more about electric fields, visit the
Web site: **physicspp.com**

CHAPTER
21 ___ Study Guide

Electric Fields

Vocabulary Review

For each description on the left, write the letter of the matching item.

_____ **1.** the ratio of an object's stored charge to its potential difference, measured in farads

_____ **2.** the vector quantity that relates the force exerted on a charge to the size of the charge

_____ **3.** the work done moving a positive test charge between two points in an electric field divided by the magnitude of the test charge

_____ **4.** the potential difference of zero between two or more positions in an electric field

_____ **5.** the lines providing a picture of the size and strength of the field around a charged object

_____ **6.** 1 J/C

_____ **7.** a device with a specific capacitance that is used in electrical circuits to store charge

a. capacitance

b. capacitor

c. electric field

d. electric field lines

e. electric potential difference

f. equipotential

g. volt

Section 21.1 ## Creating and Measuring Electric Fields

In your textbook, read about electric fields and picturing electric fields on pages 564–568.
Answer the following questions. Use complete sentences.

1. Do field lines and electric fields actually exist? How are field lines and electric fields useful?

_____

_____

_____

2. What is a Van de Graaff generator? How can one be used to show field lines?

_____

_____

_____

3. How can you find the electric field from two charges?

_____

_____

_____

4. How does Coulomb's law relate to test charges?

_____

_____

_____

5. If arrows represent electric field vectors in a picture of an electric field, how are the magnitude and the direction of the field shown?

_____

_____

_____

6. What produces an electric field?

_____

_____

_____

7. Why must you use a test charge to observe an electric field?

_____

_____

_____

8. Why should an electric field be measured by a small test charge?

_____

_____

_____

Answer the following questions. Show your calculations.

9. A negative charge of 1.4×10^{-7} C experiences a force of 1.2 N. What is the electric field magnitude at this location?

10. What charge would experience a 1.2×10^{-3} N force when in a uniform electric field of 4.4×10^6 N/C?

11. What force would be exerted on an electron in an electric field with a magnitude of 9.9×10^7 N/C?

Section 21.2 **Applications of Electric Fields**

In your textbook, read about energy and electric potential on pages 569–571.
Circle the letter of the choice that best completes the statement or answers the question.

1. A positive test charge is located at Point A. If the test charge is moved to a Point B and then back to Point A, what is the change in electric potential?

   a. The electric potential becomes zero.

   b. The electric potential decreases.

   c. The electric potential does not change.

   d. The electric potential increases.

2. Only _____ electric potential can be measured.

   a. absolute values of   **c.** differences in

   b. attractions between   **d.** points of

3. The electric potential _____ when a positive charge is moved toward a negative charge.

   a. becomes positive   **c.** increases

   b. decreases   **d.** stays the same

4. When you do positive work on a two-charge system, the electric potential energy _____.

   a. disappears   **c.** does not change

   b. decreases   **d.** increases

5. What equation defines the electric potential difference?

   a. $E = \dfrac{F}{q'}$ **c.** $V = \dfrac{J}{C}$

   b. $q = \dfrac{mg}{E}$ **d.** $\Delta V = \dfrac{W}{q'}$

In your textbook, read about electric potential in a uniform field on pages 571–572.

For each statement below, write **true** *or rewrite the italicized part to make the statement true.*

6. _____ The direction of an electric field between two parallel conducting plates is *from the positive plate to the negative plate*.

7. _____ The *electrical* difference between two points separated by a distance d in a uniform field is represented by the equation $\Delta V = Ed$.

8. _____ The potential increases in the direction *opposite* the electric field direction.

9. _____ The potential is *lower* near the positively charged plate.

10. _____ Two large, flat conducting plates parallel to each other can create a constant electric force and field. *Both are charged negatively*.

In your textbook, read about capacitance and capacitors on pages 573–579.

Answer the following questions. Show your calculations.

11. Two plates of a capacitor are 12 cm apart and have an electric field of 350 N/C. What is the potential difference between the plates?

12. How much work is done moving a positive charge of 5.1×10^{-6} C from the negative plate to the positive plate of the capacitor in Question 11?

13. What is the strength of the electric field generated by two oppositely charged plates that are 0.26 m apart and charged to a potential difference of 120 V?

14. What is the magnitude of charge on a particle if 1.4×10^{-3} J of work is needed to move the charge from one plate to another in Question 13?

In your textbook, read about storing charges on pages 577–578.

Answer the following questions. Show your calculations.

15. What is the capacitance of a sphere that is charged to 2.2×10^{-6} C and has a potential difference of 240 V with Earth?

16. What is the potential difference between a sphere and Earth if the sphere is charged to 9.6×10^{-5} C and has a capacitance of 5.8×10^{-7} C/V?

17. A constant electric field of 250 N/C is between a set of parallel plates that have a potential difference between them of 12.0 V. How far apart are the plates?

18. It takes 1.22 J to move a charge of $3.22\,\mu$C between two points in an electric field. What is the potential difference between these two points?

19. How large is the accumulated charge on one of the plates of a $45\,\mu$F capacitor when the potential difference between them is 85 V?

20. What is the voltage across a capacitor that has a charge of $133\,\mu$C and a capacitance of 12.2 pF?

CHAPTER
21 — Section 21-1 Quiz

1. An electric charge, q, produces an electric field. A test charge, q', is used to measure the strength of the field generated by q. Why must q' be relatively small?

   _____

   _____

   _____

2. Define each variable in the formula $F = Eq$.

   _____

   _____

   _____

3. Describe how electric field lines are drawn around a freestanding positive charge and a freestanding negative charge.

   _____

   _____

   _____

   _____

   _____

4. A positive charge of 1.5×10^{-8} C experiences a force of 0.025 N to the left in an electric field. What are the magnitude and direction of the field?

5. A test charge of 3.4×10^{-6} C is in an electric field with a strength of 5.1×10^{5} N/C. What is the force it experiences?

CHAPTER
21   Section 21-2 Quiz

1. How is the volt related to the joule and the coulomb?

_____

2. How does a capacitor work?

_____

_____

_____

_____

3. There is a potential difference of 120 V between two oppositely charged plates that are 14.0 cm apart. What is the magnitude of the electric field between them?

4. How much work is done to move a charge of 2.2×10^{-4} C from one plate to the other in Question 3?

5. What is the capacitance of a sphere that has been charged to 4.5×10^{-5} C when it has a potential difference of 35 V between it and Earth?

CHAPTER
21 — Reinforcement

Relationships Among Aspects of Electric Fields

Many of the relationships among the various aspects of electric fields, charges, potential differences, work, power, and capacitance are summarized in formulas. By combining these formulas, you can start with a variety of variables and combine them until only a single answer remains.

1. The formula for electric potential difference is $\Delta V = \dfrac{W}{q}$, and the formula for capacitance is $C = \dfrac{q}{\Delta V}$. Combine these two equations so that they are stated in terms of C and ΔV, and then solve for W. Show your calculations.

2. Combine your solution from Question 1 with the power equation, $P = \dfrac{W}{t}$, and solve for P in terms of C, V, and t. Show your calculations.

3. To find work done in terms of F, V, and E, combine the equation $\Delta V = \dfrac{W}{q}$ with the equation $E = \dfrac{F}{q}$, and solve for W. Show your calculations.

CHAPTER
21 — **Enrichment**

Electric Field Lines

Draw diagrams that show the electric field lines for each of the following situations.

1. a single positive charge alone

2. a single negative charge alone

3. two negative charges next to each other but not touching

4. two positive charges next to each other but not touching

5. a positive charge and a negative charge next to each other but not touching
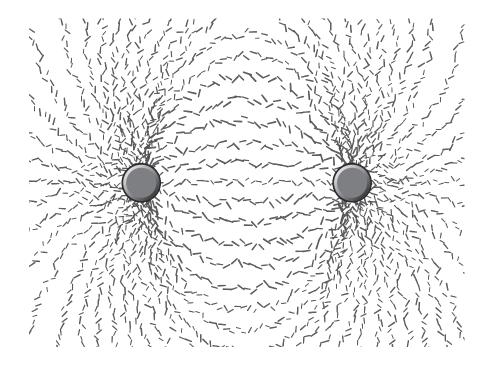
6. a positive charge next to another positive charge that is twice as strong
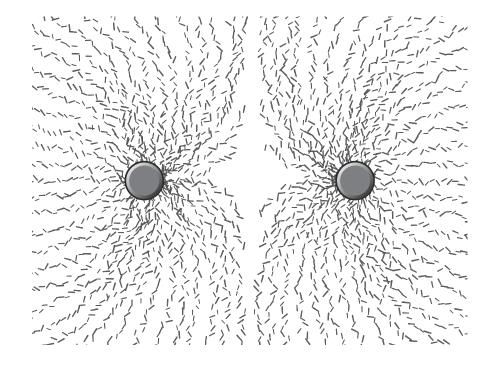
7. a positive charge between two negative charges

8. a negative charge between two positive charges

Answer the following questions. Use complete sentences.

9. How does the number of field lines on the smaller charge compare to the number of lines on the stronger charge in Question 6?

_____

_____

10. How do the field lines in Question 3 compare to the field lines in Question 4?

_____

_____

11. How do the field lines in Question 7 compare to the field lines in Question 8?

_____

_____

12. Are electric field lines real? How are they used?

_____

_____

13. Are electric fields real? How are they represented.

_____

_____

Electric Field Lines

21 ◢ Transparency 21-1 Worksheet

Electric Field Lines

1. In the figures, two charged objects are surrounded by metal filings that have been aligned by an invisible force. What is creating that force?

_____

_____

_____

2. How are the charged objects in the top figure charged? How can you tell?

_____

_____

_____

3. How are the charged objects in the bottom figure charged? How can you tell?

_____

_____

_____

_____

4. Where do the field lines coming from the positive conductor in the top figure terminate?

_____

_____

5. Where do the field lines coming from the conductors in the bottom figure terminate?

_____

_____

6. In the first figure, what do the concentric circles represent?

_____

_____

7. What does the density of the field lines represent?

_____

_____

8. Where do field lines cross one another?

_____

_____

Millikan's Apparatus

Charged plate

Microscope

Charged plate

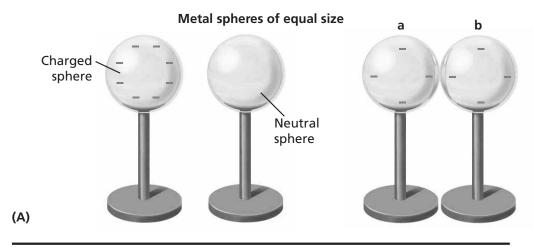Oil drop

Atomizer

Battery

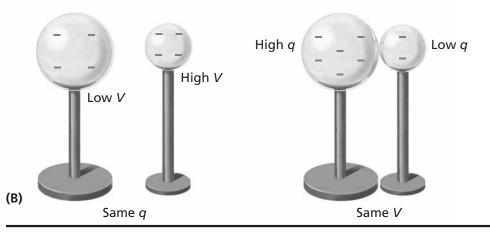# 21 — Transparency 21-2 Worksheet

Millikan's Apparatus

1. For what purpose did Millikan use this apparatus?

_____

_____

2. Under what conditions do the oil drops between the plates remain suspended in air?

_____

_____

3. For what is the atomizer used?

_____

_____

4. For what is the battery used?

_____

_____

5. How do the oil drops become charged?

_____

_____

6. Millikan's experiment showed that charge is quantized. What does this mean?

_____

_____

7. Toward which plate are the oil drops attracted?

_____

8. What role do the charged plates play in Millikan's experiment?

_____

_____

9. What values did Millikan use to calculate the charge on an electron?

_____

_____

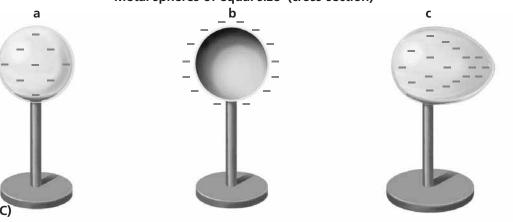**10.** What conclusion did Millikan draw about the charge of an atom?

_____

_____

Sharing Charges

Metal spheres of equal size

a   b

Charged sphere

Neutral sphere

(A)

Metal spheres of unequal size

Low V High V

High q Low q

(B) Same q Same V

Metal spheres of equal size (cross-section)

a   b   c

(C)

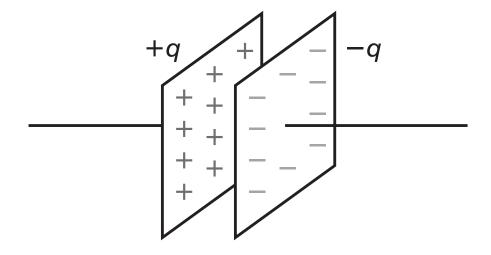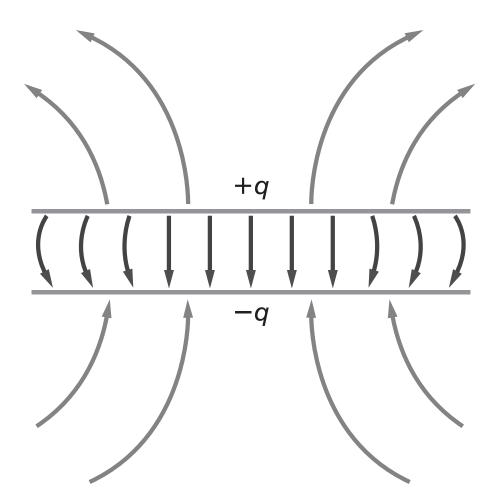## 21 _____ Transparency 21-3 Worksheet

Sharing Charges

1. Describe the relative electric potential of the two spheres on the left side of **Figure A.**

_____

_____

2. Describe the relative electric potential of the two spheres on the right side of Figure A.

_____

3. In Figure A, what happens to the charges after the charged sphere touches the neutral sphere?

_____

_____

4. Which of the four spheres in Figure A has the greatest electric potential?

_____

_____

5. In **Figure B,** in what direction do the charges move after the spheres touch?

_____

6. In Figure B, why do the charges move from one sphere to another?

_____

_____

_____

_____

7. Compare the circumstances on the right side of Figures A and B. How are they alike? How are they different?

_____

_____

_____

8. In **Figure C,** why are there no charges on the inner surface of the hollow sphere?

_____

_____

9. For the irregularly shaped conductor in Figure C, where would you expect the electric field to be strongest?

_____

Capacitor

21 ⟋⎯ Transparency 21-4 Worksheet

Capacitors

1. What are the basic characteristics of a capacitor?

_____

_____

_____

2. How does the magnitude of the charge on the negative plate relate to the magnitude of the charge on the positive plate?

_____

_____

_____

3. In which direction does the field flow between the plates?

_____

_____

4. In which direction does the field flow on the side of the negative plate near the conductor?

_____

5. In which direction does the field flow on the side of the positive plate near the conductor?

_____

_____

6. The formula for capacitance is $C = \dfrac{q}{\Delta V}$. Define all of the variables in this formula with the correct SI units.

_____

_____

_____

7. What are three modern uses for capacitors?

_____

_____

8. If the capacitor in the figure has been charged to 5.8×10^{-6} C at a location where it has a potential difference with Earth of 60 V, what is its capacitance?

CHAPTER
21 — Chapter Assessment

Electric Fields
Understanding Physics Concepts
For each phrase on the left, write the letter of the matching item.

_____ **1.** 1 J/C

_____ **2.** the work done moving a positive test charge between two points in an electric field divided by the magnitude of the test charge

_____ **3.** a device with a specific capacitance that is used in electric circuits to store charge

_____ **4.** the ratio of an object's stored charge to its potential difference, measured in farads

_____ **5.** the vector quantity that relates the force exerted on a charge to the size of the charge

_____ **6.** the lines that provide a picture of the size and strength of the field around a charged object

_____ **7.** the potential difference of zero between two or more positions in an electric field

a. electric field

b. electric field line

c. electric potential difference

d. volt

e. equipotential

f. capacitor

g. capacitance

Circle the letter of the choice that best completes the statement.

8. A _____ is a device that accumulates a charge.

   a. Leyden jar   **c.** Van de Graaff generator

   b. lightning rod   **d.** None of the above

9. An electric field is equal to force _____.

   a. per unit charge   **c.** per unit time

   b. per unit mass   **d.** times direction

10. As an electric field becomes stronger, the field lines should be drawn _____.

   a. closer together   **c.** thicker

   b. father apart   **d.** thinner

11. The force on a test charge in an electric field is _____ the magnitude of the field.

   a. directly proportional to   **c.** inversely proportional to the square of

   b. inversely proportional to   **d.** unrelated to

12. The strength of the force on a charge in an electric field depends on _____.

   a. the size of the charge   **c.** the magnitude of the field

   b. the direction of the field   **d.** both the magnitude of the field and size of the charge

For each statement below, write true *or rewrite the italicized part to make the statement true.*

13. _____ A *capacitor* is made up of two conductors separated by an insulator.

14. _____ A device with a specific capacitance that is used in electrical *circuits* to store charge is called a capacitor.

15. _____ A *farad* is a joule per coulomb.

16. _____ In a uniform electric field, the potential difference between two points is found using the equation $\Delta V = Ed$.

17. _____ Robert Millikan determined that the charge on a *proton* is equal to 1.6×10^{-19} C.

18. _____ The charges on a hollow conductor are found on the *inner* surface.

19. _____ Touching an object to Earth to eliminate excess charge is called *grounding*.

20. _____ When potential difference is zero between two or more positions in an electric field, they are said to be *at potential difference*.

21. _____ With two *like* charges, you must do work to pull one charge away from the other.

Write the term that correctly completes the statement.

22. _____ An electric field produces _____ on other charged objects.

23. _____ Electric field lines are directed away from _____ charges and _____ negative charges

24. _____ Electric field lines never _____, and the closer they are, the _____ the electric field.

25. _____ Electric potential difference is measured in _____.

26. _____ _____ makes the potential difference between an object and Earth equal to zero.

27. _____ Electric fields are strongest near sharply pointed _____.

28. _____ _____ are used to store charge.

Thinking Critically

Answer the following questions. Show your calculations.

1. How much work is done to transfer 1.20 C of charge through a potential difference of 48.0 V?

2. The electric field intensity between two charged plates is 1.9×10^4 N/C. The plates are 4.6 cm apart. What is the potential difference between the plates in volts?

3. A 6.0-V battery does 1200 J of work transferring charge. How much charge is transferred?

4. A voltmeter connected between two plates registers 26 V. The plates are 0.022 m apart. What is the field intensity between the plates?

5. What charge does a test charge have when a force of 2.21×10^{-5} N acts on it at a point where the electric field intensity is 3.30×10^{-6} N/C?

6. A force of 0.55 N acts on a positive charge of 8.8×10^{-6} C at a certain distance. What is the electric field intensity at that distance?

7. It takes 3.3 J of energy to move a 1.2 C charge through part of an electric field. What is the potential difference between these two points?

8. A constant electric field of 555 N/C is between a set of parallel plates that have a potential difference between them of 12.2 V. How far apart are the plates.

9. What force is exerted on a 19.9 C charge by an electric field of 4.54×10^{-4} N/C?

10. A positive charge of 3.4 mC experiences a 7.7×10^{-8} N force when placed in an electric field. What is the strength of the electric field?

Applying Physics Knowledge

Answer the following questions. Use complete sentences.

1. Compare and contrast an electric field and a gravitational field.

   _____

   _____

   _____

   _____

   _____

   _____

2. Why is electric potential energy larger when two like charges are close together than when two unlike charges are close together?

   _____

   _____

   _____

   _____

3. If a high-voltage wire falls on a car, will the people inside be safe from electrocution? Why or why not?

   _____

   _____

   _____

   _____

4. What is the direction of an electric field between a negatively charged plate and a positively charged plate in a capacitor?

   _____

   _____

   _____

5. What is the net charge on a capacitor? Why?

_____

_____

_____

Answer the following questions. Show your calculations.

6. How much energy is stored in a capacitor of 14.4 μF that has been charged to 955 V?

7. How much power is needed to charge a capacitor of 22 μF to 980 V in 25 s?

8. How much work is done by a system in which the force is 2.8×10^4 N, the potential difference is 11 V, and the electric field intensity is 3.9×10^{-3} N/C?

9. What is the potential difference of a system in which a 4.7×10^3 N force moves a 2.6×10^{-2} C charge through a uniform electric field a distance of 24 cm?

Current Electricity

CHAPTER
22   Mini Lab Worksheet

Current Affairs

Do you think that current diminishes as it passes through different elements in the circuit? As a scientist, you can test this question.

1. Draw a circuit that includes a power supply and two miniature lamps.

2. Draw the circuit again and include an ammeter to measure the current between the power supply and the lamps.

3. In a third diagram, show the ammeter at a position to measure the current between the lamps.

Analyze and Conclude

4. **Predict** if the current between the lamps will be more than, less than, or the same as the current before the lamps. Explain.

   _____

   _____

5. **Test** your prediction by building the circuits. *CAUTION: Wire is sharp and can cut skin.*

CHAPTER
22 Physics Lab Worksheet

Materials

▢ ▢ ▢ ▢

■ *CAUTION: Resistors and circuits may become hot.*

■ *CAUTION: Wires are sharp and can cut skin.*

• four 1.5-V D batteries

• four D-battery holders

• one 10-kΩ resistor

• one 500-μA ammeter

• five wires with alligator clips

• one 20-kΩ resistor

• one 30-kΩ resistor

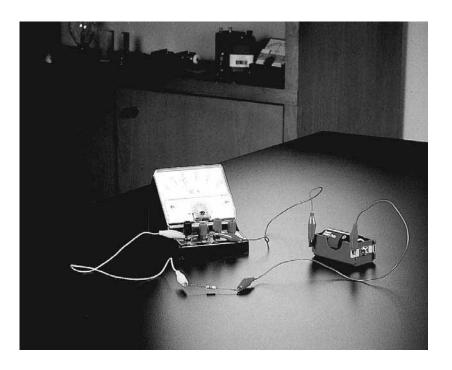• one 40-kΩ resistor

Voltage, Current, and Resistance

In this chapter, you studied the relationships between voltage, current, and resistance in simple circuits. Voltage is the potential difference that pushes current through a circuit, while resistance determines how much current will flow if a potential difference exists. In this activity, you will collect data and make graphs in order to investigate the mathematical relationships between voltage and current and between resistance and current.

Question

What are the relationships between voltage and current and resistance and current?

Objectives

■ **Measure** current in SI.

■ **Describe** the relationship between the resistance of a circuit and the total current flowing through a circuit.

■ **Describe** the relationship between voltage and the total current flowing through a circuit.

■ **Make and use graphs** to show the relationships between voltage and current and between resistance and current.

22 ⟋‾‾⟍ **Physics Lab Worksheet** *continued*

Data Table 1		
Voltage (V)	Resistance (kΩ)	Current (μA)
1.5		
1.5		
1.5		
1.5		

Data Table 2		
Voltage (V)	Resistance (kΩ)	Current (μA)
	10	
	10	
	10	
	10	

Procedure

Part A

1. Place the D battery in the D-battery holder.

2. Create a circuit containing the D battery, 10-kΩ resistor, and 500-μA ammeter.

3. Record the values for resistance and current in Data Table 1. For resistance, use the value of the resistor. For current, read and record the value given by the ammeter.

4. Replace the 10-kΩ resistor with a 20-kΩ resistor.

5. Record the resistance and the current in Data Table 1.

6. Repeat steps 4–5, but replace the 20-kΩ resistor with a 30-kΩ resistor.

7. Repeat steps 4–5, but replace the 30-kΩ resistor with a 40-kΩ resistor.

Part B

8. Recreate the circuit that you made in step 2. Verify the current in the circuit and record the values for voltage and current in Data Table 2.

9. Add a second 1.5-V D battery to the setup and record the values for voltage and current in Data Table 2. When you are using more than one battery, record the sum of the batteries' voltages as the voltage in Data Table 2.

10. Repeat step 9 with three 1.5-V D batteries.

11. Repeat step 9 with four 1.5-V D batteries.

Analyze

1. **Make and Use Graphs** Graph the current versus the resistance. Place resistance on the *x*-axis and current on the *y*-axis.

2. **Make and Use Graphs** Graph the current versus the voltage. Place voltage on the *x*-axis and current on the *y*-axis.

3. **Error Analysis** Other than the values of the resistors, what factors could have affected the current in Part A? How might the effect of these factors be reduced?

_____

_____

_____

4. **Error Analysis** Other than the added batteries, what factors could have affected the current in Part B? How might the effect of these factors be reduced?

_____

_____

_____

Conclude and Apply

1. Looking at the first graph that you made, describe the relationship between resistance and current?

_____

_____

_____

2. Why do you suppose this relationship between resistance and current exists?

_____

_____

_____

3. Looking at the second graph that you made, how would you describe the relationship between voltage and current?

_____

_____

_____

4. Why do you suppose this relationship between voltage and current exists?

_____

_____

_____

Going Further

1. What do you suppose would be the current at a voltage of 3.0 V and a resistance of 20 kΩ? How did you determine this?

_____

_____

2. Could you derive a formula from your lab data to explain the relationship among voltage, current, and resistance? *Hint: Look at the graph of current versus voltage. Assume it is a straight line that goes through the origin.*

_____

_____

3. How well does your data match this formula? Explain.

_____

_____

Real-World Physics

1. Identify some common appliances that use 240 V rather than 120 V.

_____

_____

2. Why do the appliances that you identified require 240 V? What would be the consequences for running such an appliance on a 120-V circuit?

_____

_____

_____

_____

Physics **nline**

To find out more about current electricity, visit the Web site: **physicspp.com**

CHAPTER

22 — Study Guide

Current Electricity

Vocabulary Review

Write the term that correctly completes the statement. Use each term once.

ampere	**electric current**	**resistor**
battery	**kilowatt-hour**	**series connection**
conventional current	**parallel connection**	**superconductor**
electric circuit	**resistance**	

1. _____ A(n) _____ is a material with zero resistance.

2. _____ The _____ of a wire determines how much current will flow through the wire when a voltage is applied.

3. _____ The _____ is the flow of charged particles.

4. _____ In a(n) _____, there is only one path for the current.

5. _____ A(n) _____ is a unit of energy.

6. _____ In a(n) _____, there is more than one path for the current.

7. _____ A(n) _____ is the unit of current.

8. _____ A(n) _____ is a closed loop in which electrons can move.

9. _____ A(n) _____ converts chemical energy to electrical energy.

10. _____ A(n) _____ is the flow of positive charge.

11. _____ A(n) _____ is a device designed to have a specific resistance.

Section 22.1 — Current and Circuits

In your textbook, read about electric circuits on pages 591–593.
*For each statement below, write **true** or rewrite the italicized part to make the statement true.*

1. _____ *Negative* charge flows from a higher potential to a lower potential.

2. _____ The flow of *electrons* is called conventional current.

3. _____ The total charge passing through a point on a circuit is the current multiplied by the *time* the charge flows.

4. _____ Electrical energy is converted into kinetic energy in a *generator*.

5. _____ The number of *electrons* in a closed circuit does not change.

Write the term that correctly completes the statement.

A circuit includes a (**6**) _____, which increases the potential energy of the

charge, and a device that (**7**) _____ the potential energy of the charge.

The potential energy lost by the charges is usually converted into another form of

(**8**) _____. For example, a lamp converts electrical energy to

(**9**) _____ energy.

Read the passage below to answer questions 10–13.

A closed circuit consists of a battery of constant voltage connected to a heater with wires. Electrons are flowing through the circuit, causing the heater to emit thermal energy.

10. Draw a sketch of the circuit.

11. What do the battery and the heater do to the electrons?

_____

_____

_____

12. What does the law of conservation of electric charge state?

_____

13. Is it possible for the current leaving the heater to be different than the current entering the heater? Why or why not?

_____

_____

_____

In your textbook, read about rates of charge flow and energy transfer on pages 593–594.

Circle the letter of the choice that best completes the statement.

14. Power is measured in units called _____.

    a. amperes   **c.** kilowatt-hours

    b. joules   **d.** watts

15. Current is measured in units called _____.

    a. amperes   **c.** potential

    b. kilowatt-hours   **d.** watts

16. If a 9.0-V battery delivers 0.50 A of current to a heater, the power consumed by the heater is _____.

    a. 0.056 W   **c.** 9.0 W

    b. 4.5 W   **d.** 18 W

17. If a light bulb is rated at 50 W, the amount of energy consumed in 30 minutes is _____.

    a. 2 kWh   **c.** 30 J

    b. 30 kWh   **d.** 90,000 J

Write the term that correctly completes the statement.

(18) _____ measures the rate at which energy is transferred. The formula for

the power is **(19)** _____. The energy carried by an electric current depends on

the **(20)** _____ transferred and the **(21)** _____

difference the charge undergoes. The formula for the amount of energy transferred is

(22) _____. The rate of flow of the charge is called the electric

(23) _____. The formula for the rate of flow of charge is

(24) _____. Another formula for the power delivered by an electric

current is **(25)** _____.

In your textbook, read about resistance and Ohm's law on pages 595–597.

Circle the letter of the choice that best completes the statement.

26. A battery with a voltage of 9.0 V is connected to a lamp. The current flowing in the circuit is 0.30 A. The resistance of the lamp is _____.

    a. 0.030 Ω   **c.** 27 Ω

    b. 2.7 Ω   **d.** 30 Ω

22 **Study Guide**

27. For a wire that obeys Ohm's law, the resistance of a wire depends on the _____ the wire.

    a. current in

    b. length of

    c. power delivered by

    d. voltage across

28. If a 200-Ω resistor is connected to a 5-V battery, the current in the circuit will be _____.

    a. 0.025 A

    b. 2.5 A

    c. 40 A

    d. 1000 A

29. A device that can be used to change the current in a circuit in a continuous way is a _____.

    a. potentiometer

    b. battery

    c. motor

    d. lamp

Answer the following questions.

30. Draw a circuit diagram with a resistor, ammeter, and battery. Connect the ammeter in series with the other two components.

31. Draw a circuit diagram with a resistor, battery, and voltmeter. Connect the voltmeter in parallel across the resistor. Draw another circuit diagram showing the voltmeter connected in parallel across the battery.

Section 22.2 **Using Electric Energy**

In your textbook, read about energy transfer on pages 601–603.

Answer the following questions. Show your calculations.

1. A 9.0-V battery is connected to a lightbulb with a resistance of 100 Ω. What is the power delivered to the light bulb?

2. A source of potential difference of 110 V is used to operate a heater with a resistance of 220 Ω. How much energy is consumed in a 24-h day?

3. Why does a resistor heat up when an electric current flows through it?

_____

_____

_____

4. List at least five appliances designed to convert electric energy into thermal energy.

_____

_____

_____

5. Is it OK to connect a 100-V toaster to a 220-V circuit? Why or why not? Explain.

_____

_____

_____

For each description on the left, write the letter of the matching term on the right.

_____   **6.** converts kinetic energy to electric energy   **a.** heater

_____   **7.** designed to convert electric energy to thermal energy   **b.** battery

_____   **8.** converts electric energy to kinetic energy   **c.** solar cell

_____   **9.** designed to convert electric energy to light energy   **d.** generator

_____   **10.** converts light energy to electric energy   **e.** lamp

_____   **11.** converts chemical energy to electric energy   **f.** motor

In your textbook, read about the transmission of electric energy transfer on pages 603–604.
Circle the letter of the choice that best completes the statement or answers the question.

12. The formula for power loss in a wire is _____.

   a. $P = IR^2$ **c.** $P = I^2R$

   b. $P = IR$ **d.** $P = RV$

13. In the transmission of electric energy, some power is lost to thermal energy. Electrical engineers call this unwanted thermal energy the _____.

   a. joule heating loss   **c.** output voltage

   b. resistance   **d.** long-distance line

14. The purpose of increasing the voltage when transmitting electric power over long distances is to _____.

   a. decrease joule heating loss   **c.** increase current in wire

   b. decrease resistance of wires   **d.** increase kilowatt-hours

15. The kilowatt-hour is a unit of _____.

   a. current   **c.** potential

   b. energy   **d.** power

16. A 60-W lightbulb illuminated day and night for 30 days consumes _____ of energy.

   a. 43.2 J   **c.** 1800 kWh

   b. 43.2 kWh   **d.** 1.5×10^{12} J

17. If a family's electric bill is $74.00 per month and the cost of electricity is $0.12 per kWh, how much electricity does the family use per month?

   a. 8.9 kWh   **c.** 620 kWh

   b. 270 kWh   **d.** 620×10^2 kWh

CHAPTER

22 — Section 22-1 Quiz

1. If 20 coulombs of charge move past a given point in 4 s, what is the current?

2. A 6.0-V battery delivers a 0.5 A current to an electric motor connected across its terminals. What is the power of the motor?

3. What are four factors that affect the resistance properties of a piece of metal wire?

   _____

   _____

4. A resistance of 30 Ω is placed across a 90-V battery. What current flows in the circuit?

5. A current of 0.50 A is carried through a lamp when it is connected to a 120-V source. What is the resistance of the lamp?

6. Why do ammeters have low resistance?

   _____

   _____

   _____

   _____

CHAPTER
22 — Section 22-2 Quiz

1. When you feel a small electric shock such as the small spark you might experience when touching a metal object on a dry day, does the voltage or the current cause the sensation?

   _____

   _____

   _____

2. Why do wires heat up when a current flows in them?

   _____

   _____

   _____

3. A heating coil has a resistance of 100 Ω. It is designed to operate on 120 V. What is the power consumed by the heating coil?

4. How much energy, in joules, does a 100-W lightbulb use in 20 s?

5. How much energy, in kilowatt-hours, does a 40-W lightbulb use in one year?

6. The electric power generated at an electric power plant has high current and low voltage. Why is a transformer used to decrease the current and increase the voltage of the electric power before the power is delivered to the consumer?

   _____

   _____

   _____

CHAPTER
22 Reinforcement

Materials

• pencil
• paper
• graph paper

Ohm's Law

Problem

How do you use Ohm's Law to determine the voltage, current, and resistance of an electrical circuit?

Procedure

1. On a piece of paper, draw the symbols for a battery, potentiometer (variable resistor), ammeter, and voltmeter.

2. Draw a circuit schematic of a closed series circuit containing the potentiometer, ammeter, and battery.

Results

1. Assume that the voltage of the battery is 250 V, the resistance of the potentiometer can be set at all values from 1 Ω to 500 Ω, and the resistance of the ammeter and battery is zero. Create a table of values that shows the current in the ammeter for different values of the variable resistor using 1.0 Ω, 1.0×10^2 Ω, 2.0×10^2 Ω, 3.0×10^2 Ω, 4.0×10^2 Ω, 5.0×10^2 Ω.

2. Draw a graph of the values in your table on a piece of graph paper. Label the vertical and horizontal axes.

3. Draw a parallel circuit containing the battery, potentiometer, and voltmeter that can be used to measure the voltage difference across the potentiometer.

—
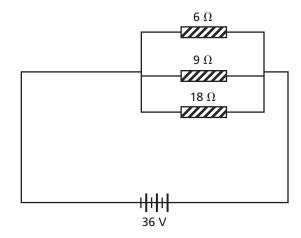
CHAPTER
22   Enrichment

Materials

👓 🧤

- pencil
- paper
- graph paper

Ohm's Law

6 Ω

9 Ω

18 Ω

36 V

Problem

How do you use Ohm's Law to determine the voltage, current, and resistance of a parallel electric circuit and a series electric circuit?

Procedure

Components in an electric circuit may be connected either in series or in parallel. The circuit above shows three resistors connected in parallel to a battery. No matter how they are connected, all components obey Ohm's law or some variation derived from the original equation.

Results

1. The voltage of the battery is 36 V. In a parallel circuit, the voltage across each resistor is the same as the battery voltage but the current depends on the resistance of each branch. What is the current in each of the branches of the circuit?

2. The three resistors in parallel have the same resistance as a single resistor of 3 Ω. What is the total current going through the battery?

3. Draw a circuit schematic of a series circuit containing a 6-Ω, 9-Ω, and 18-Ω resistor with one branch. Resistors connected in series act together as a single resistor with a value equal to the sum of all resistors in that combination. What is the resistance of a single resistor that draws the same current from the battery as the three resistors in series?

4. Why is the answer to question 3 different from the answer to question 2?

_____

_____

_____

5. The resistances described in Questions 2 and 3 are called the *equivalent resistance*. Using Ohm's law, derive a formula for the equivalent resistance of resistors 1, 2, and 3 with resistances R_1, R_2, and R_3 when the resistors are connected in series. Also derive a formula for the equivalent resistance when they are connected in parallel.

Parts of an Electric Circuit

Battery

Switch

Lamp

Conductor

Open circuit

Power source
(Battery)

Conductor
(Wire)

Switch
(Open)

Load/Resistor
(Lamp)

Closed circuit

Power source
(Battery)

3 V

Direction of
current

I

I

Conductor
(Wire)

Switch
(Closed)

Load/Resistor
(Lamp)

30 Ω

22 ⟋‾‾ Transparency 22-1 Worksheet
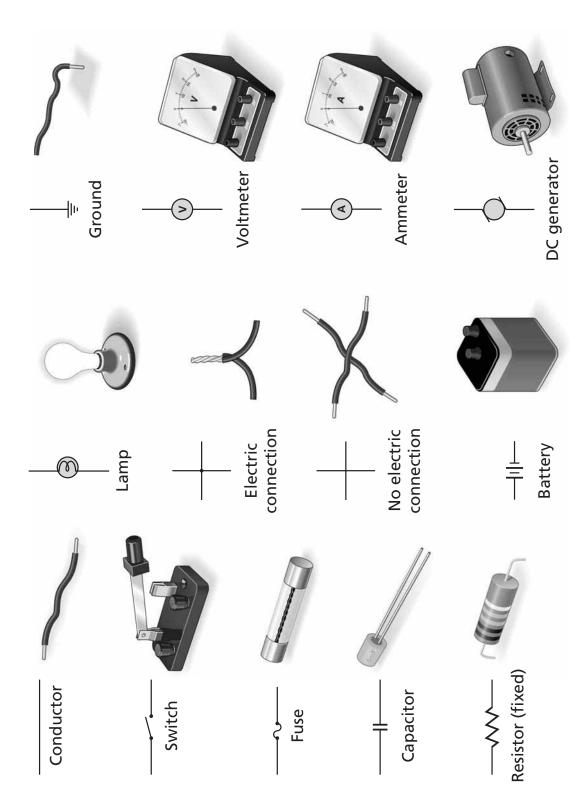
Parts of an Electric Circuit

1. How much power does the bulb use when it is turned on?

2. What is the magnitude of the current that flows through the circuit shown when the switch completes the circuit?

3. What happens to the amount of power the bulb uses if the resistance of the bulb is increased? What happens to the power if the resistance is decreased?

   _____

   _____

   _____

4. How much energy does the lightbulb use in 1 h?

Circuit Symbols

Ground

Voltmeter

Ammeter

DC generator

Lamp

Electric connection

No electric connection

Battery

Conductor

Switch

Fuse

Capacitor

Resistor (fixed)

22 ⎯ **Transparency 22-2 Worksheet**

Circuit Symbols
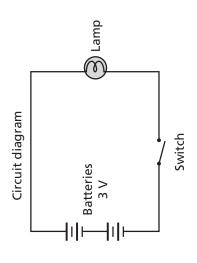
1. What is resistance? What factors affect resistance?

_____

_____

_____

_____

_____

_____
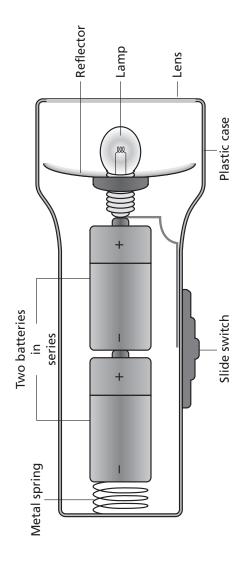
2. What is the difference between current and voltage?

_____

_____

_____

_____

_____

_____

_____

_____

3. Different resistors of progressively increasing resistance are connected to a 12-V battery. What happens to the current in the circuit as the resistance in the circuit increases?

_____

_____

_____

4. How are circuit diagrams useful?

_____

_____

_____

Inside a Flashlight

Circuit diagram

Lamp

Batteries
3 V

Switch

Reflector

Lamp

Lens

Plastic case

Two batteries
in
series

+

−

+

−

Slide switch

Metal spring
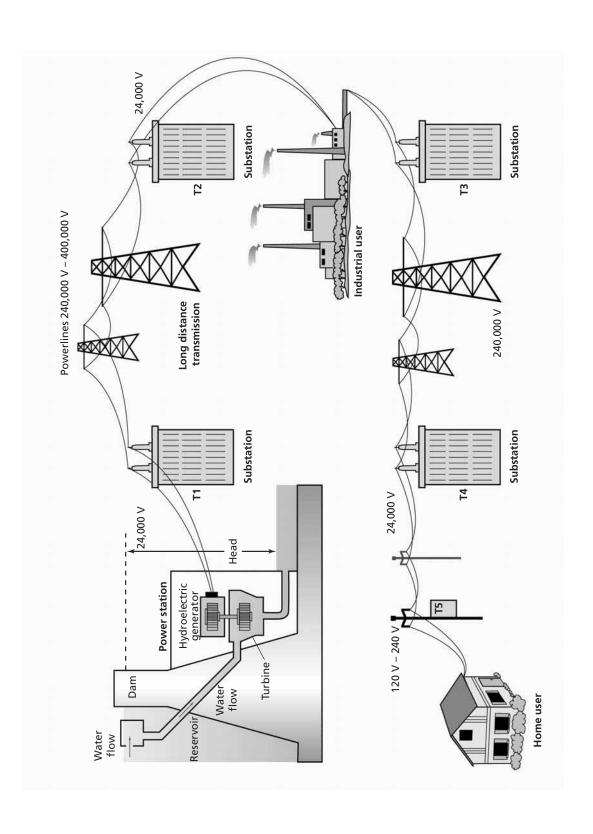
22   Transparency 22-3 Worksheet

Inside a Flashlight

1. In what direction is the current carried in the flashlight shown?

_____

2. What happens in the circuit when the switch is moved from the off position to the on position?

_____

_____

_____

_____

_____

_____

_____

_____

3. What would happen to the current through the bulb if the voltage in the circuit were increased?

_____

_____

_____

4. What is the relationship between the amount of energy the flashlight uses per unit of time and the voltage of the batteries connected to the flashlight?

_____

_____

_____

_____

Electric Power Transmission

22 ⟋ Transparency 22-4 Worksheet

Electric Power Transmission

1. Describe the relationship between the magnitude of the current in transmission wires and the amount of thermal energy lost in transmission wires.

_____

_____

_____

2. Why is it important to minimize current in transmission wires?

_____

_____

_____

3. How is power transmitted with minimal loss of thermal energy?

_____

_____

_____

4. Why are voltages reduced for use in homes?

_____

_____

_____

_____

CHAPTER
22 ⎯ Chapter Assessment

Current Electricity

Understanding Physics Concepts

For each physical quantity on the left, write the letter of the matching unit of measurement on the right.

_____ **1.** charge   **a.** watt

_____ **2.** potential energy   **b.** ohm

_____ **3.** current   **c.** coulomb

_____ **4.** resistance   **d.** joule

_____ **5.** potential   **e.** ampere

_____ **6.** power   **f.** volt

Circle the letter of the choice that best completes the statement.

7. A conventional current is the flow of _____.

  a. alternating current   **c.** electrons or ions

  b. electrons   **d.** positive charge

8. The conservation of charge in a circuit implies that _____.

  a. electrons cannot be created   **c.** electrons can move through the circuit
      or destroyed

  b. the total amount of charge   **d.** all of the above
      is constant

9. The potential difference between two points in space is 1000 V, and 2 coulombs of charge is transferred from the point of lower potential to the point of higher potential. The amount of work done is _____.

  a. 2×10^{-3} J   **c.** 1000 J

  b. 500 J   **d.** 2000 J

10. A 9-V battery is connected to a toy car, and the current produced is 2 A. The rate at which energy is delivered to the toy car is _____.

  a. 4.5 J   **c.** 4.5 W

  b. 18 J   **d.** 18 W

11. A 60-W lightbulb runs for 2 hours. The energy consumed is _____.

  a. 30 J   **c.** 120,000 J

  b. 120 J   **d.** 432,000 J

12. A heater that operates at 220 W is connected to a 110-V outlet. The current that flows through the heater is _____.

  a. 0.5 A   **c.** 2.2 A

  b. 2 A   **d.** 20 A

13. A lamp is connected to a battery of 50 V, and the current that flows through the circuit is 2 A. The resistance of the lamp is _____.

   a. 0.04 Ω   **c.** 100 Ω

   b. 25 Ω   **d.** 150 Ω

14. The current through a resistor of 15 Ω is 5.0 A. The voltage drop across the resistor is _____.

   a. 0.33 V   **c.** 45 V

   b. 3.0 V   **d.** 75 V

15. A series circuit has a power source of 120 V and a 150-Ω resistor. The power delivered by the power source is _____.

   a. 96 W   **c.** 9.6 kW

   b. 192 W   **d.** 96 kW

16. The rating of a lightbulb is 100 W and its resistance is 50 Ω. The current through the lightbulb when it is on is _____.

   a. 0.5 A   **c.** 2 A

   b. 1.4 A   **d.** 5000 A

17. The amount of energy consumed by a 150-W lightbulb in 24 h is _____.

   a. 3.6 J   **c.** 3.6 kWh

   b. 130,000 J   **d.** 3×10^3 kWh

18. A household's electric bill is $56 for the month of February and the cost of electricity is $0.12 per kilowatt-hour. The household used _____ of energy in this month.

   a. 6.7 kW   **c.** 467 kWh

   b. 467 kJ   **d.** none of the above

19. A conducting wire has a resistance of 0.02 Ω/m. The rate at which power is dissipated in a 100-m wire when it carries a current of 20 A is _____.

   a. 0.8 J/s   **c.** 800 J

   b. 8 W   **d.** 800 W
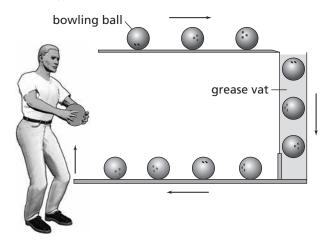
Draw circuit diagrams of the following closed circuits.

20. A battery is connected in series with a resistor and an ammeter.

21. A battery is connected to a resistor, and a voltmeter is connected in parallel.

Thinking Critically

Refer to the diagram below to answer questions 1–5.

In the diagram, a man is moving grease through a long narrow tank by dropping bowling balls into the grease. The weight of the bowling ball pushes the grease along as a continuous flow. When a bowling ball reaches the bottom of the tank, a special valve enables the man to retrieve the ball and lift it up again. This diagram provides a simple model of electricity moving through a circuit with a resistor, with the man acting as a battery or other power source.

1. Draw the circuit diagram for a battery connected to a resistor.

2. In what way is the man in the diagram similar to the battery in the above circuit?

_____

_____

_____

3. Assuming that the grease is so viscous that the speed of the bowling ball at the bottom of the vat is zero, what happens to the gravitational potential energy of the bowling ball?

_____

_____

_____

4. In what way are the bowling balls similar to electrons?

_____

_____

_____

_____

5. In what way are the horizontal tracks similar to connecting wires?

_____

_____

_____

For the following experimental results, provide an explanation or theory.

6. The resistance of a wire increases as its length increases.

_____

_____

_____

7. The resistance of a wire increases as its cross section decreases.

_____

_____

_____

8. The resistance of a wire increases as its temperature increases.

_____

_____

_____

9. Does the theory in the answer to question 6 explain why resistance depends on the material the resistor is made of ?

_____

_____

_____

Applying Physics Knowledge

Answer the following questions.

1. Draw a circuit diagram of a closed circuit connecting a 36-V battery, a potentiometer, an ammeter, a bulb, and voltmeter. The voltmeter is connected in parallel across the potentiometer, and the other components are connected in series.

2. Suppose that the initial setting of the potentiometer in Question 1 is 1 Ω. Construct a table of values showing the current in the lamp as the resistance of the potentiometer increases from 1 Ω to 100 Ω, 200 Ω, and finally, 300 Ω.

3. Suppose an ammeter reads 1.0 A, 0.12 A, 0.18 A, and 0.36 A. Construct a table showing the resistance of the potentiometer for each reading on the ammeter.

4. A wire is connected to a 9-V battery and ammeter, and its resistance is measured. The length of the wire is varied, and the values shown in the table are obtained.

Current (A)	Length (m)
12.7	1
6.4	2
4.3	3
3.2	4
2.6	5

Create a table of values comparing the resistance of the wire with the length. Graph the table and derive a formula for the resistance of a wire in terms of its length.

Read the passage below to answer questions 5–7.

A model of a metal is that it is a *sea of electrons*. This model is based on the fact that, in a metal, the outer electrons of the atoms of the metal are not tightly bonded to any particular atom and are free to move.

5. Why does the resistance of a wire decrease as the thickness of the wire increases?

_____

_____

_____

6. Experiments show that the resistance of a wire is inversely proportional to the square of its diameter. How do you explain this?

_____

_____

_____

7. The actual speed of electrons moving in a wire is called the *drift velocity* and is of the order of magnitude of 1 cm/h. Is the smallness of the drift velocity consistent with the above model? Why do people think electricity travels fast?

_____

_____

_____

_____

Reproducible Pages Contents

Series and Parallel Circuits

CHAPTER
23 — Mini Lab Worksheet

Parallel Resistance ▨▨▨▨

Hook up a power supply, a resistor, and an ammeter in a series circuit.

1. **Predict** what will happen to the current in the circuit when a second, identical resistor is added in parallel to the first.

2. **Test** your prediction.

3. **Predict** the new currents when the circuit contains three and four identical resistors in parallel.

4. **Test** your prediction.

Analyze and Conclude

5. **Make** a data table to show your results.

6. **Explain** your results. *(Hint: Include the idea of resistance.)*

_____

_____

_____

_____

CHAPTER

23 — Physics Lab Worksheet

Materials

- ■ **Hazard from electric shock is minimal because of the low currents used in this experiment. This experiment should not be carried out using current from an AC circuit, as this current is deadly.**

- ■ **Handle wire ends with care as they may be sharp and could cause cuts.**

- low-voltage power supply
- two light sockets
- two small lightbulbs
- ammeter or multimeter (0–500-mA scale)
- voltmeter or multimeter (0–30-V scale)
- about ten copper wires with alligator clips

Series and Parallel Circuits

In every circuit there is a relationship among current, potential difference, and resistance in electric circuits. In this experiment, you will investigate how the relationship of current, potential difference, and resistance in series circuits compares to that in parallel circuits.

Question

How do current, potential difference, and resistance compare in series and parallel circuits?
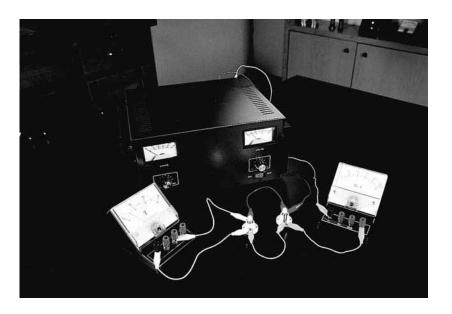
Objectives

- ■ **Describe** the relationship among current, potential difference, and resistance in a series circuit.

- ■ **Summarize** the relationship among current, potential difference, and resistance in a parallel circuit.

- ■ **Collect data** for current and potential difference using electric meters.

- ■ **Calculate** resistance in a lightbulb from current and potential-difference data.

Procedure

1. Wire two lightbulb sockets in series with an ammeter and a low-voltage power supply. Observe the correct polarity when wiring the ammeter.

Data Table	
Step	**Observations**
3	
4	
5	
6	
8	
9	
10	
11	

2. Screw the lightbulbs into the sockets. Turn on the power supply. Adjust the power control so that the bulbs are dimly lit.

3. Unscrew one of the bulbs. Record your observations in the data table.

4. Find the potential difference across both sets of bulbs by placing the positive probe of the voltmeter on the positive end of the circuit and the negative probe on the negative end of the circuit. Record your data in the data table.

5. Find the potential difference across each individual lightbulb by placing the positive probe of the voltmeter on the positive end of a bulb and the negative probe on the negative end of the bulb. Record your data in the data table. Repeat for the other bulb in series.

6. Place the ammeter at various locations in the series circuit. Record these currents in the data table.

7. Wire the two lightbulb sockets in parallel with the low-voltage power supply and in series with an ammeter.

8. Screw the lightbulbs into the sockets. Turn on the power supply. Adjust the power control so that the bulbs are dimly lit. Record the current shown on the ammeter in the data table.

9. Check the potential difference across the entire circuit and across each lightbulb. Record the values in the data table.

10. Place the voltmeter probes across one of the lightbulbs. Now unscrew one of the lightbulbs. Record your observations of both lightbulbs, and record the current and potential difference read by the meters in the data table.

11. Return the lightbulb you removed in the previous step to its socket. Now unscrew the other light-bulb. Record your observations of both lightbulbs, and record the current and potential difference read by the meters in the data table.

Analyze

1. Calculate the resistance of the pair of lightbulbs in the series circuit.

2. Calculate the resistance of each lightbulb in the series circuit.

3. How does the resistance of the pair of lightbulbs compare to the individual resistance of each lightbulb?

_____

_____

_____

4. How does the potential difference across the individual lightbulbs compare to the potential difference across the pair of lightbulbs in the series circuit?

_____

_____

_____

5. Calculate the resistance of each of the lightbulbs while they are in the parallel circuit. How does this compare to the resistance calculated for the bulbs in the series circuit?

_____

_____

_____

6. Why does the lightbulb get brighter in the parallel circuit when the other bulb is unscrewed?

_____

_____

_____

23   Physics Lab Worksheet

Conclude and Apply

1. Summarize the relationship among current, potential difference, and resistance in a series circuit.

_____

_____

_____

2. Summarize the relationship between current and potential difference in a parallel circuit.

_____

_____

_____

Going Further

Repeat the experiment using lightbulbs of different voltage ratings (for example: 1.5 V, 3.0 V, and 6.0 V).

Real-World Physics

1. The lightbulbs in most homes all are rated for 120 V, no matter how many bulbs there are. How does the way in which the bulbs are wired (series or parallel) affect your ability to use the same voltage bulbs without regard to how many are used?

_____

_____

_____

2. Why do lights in a home dim when a large appliance, such as an air conditioner, is turned on?

_____

_____

_____

Physics Online

To find out more about series and parallel circuits, visit the Web site: **physicspp.com**

CHAPTER
23 Study Guide

Series and Parallel Circuits

Vocabulary Review

For each description on the left, write the letter of the matching item.

_____ **1.** a circuit in which all current travels through each device

_____ **2.** a short piece of metal that melts if a current that is too large passes through it

_____ **3.** the occurrence when a circuit forms that has a very low resistance

_____ **4.** a circuit in which there are several different paths for a current

_____ **5.** an automatic switch that opens a circuit when the current reaches some set value

_____ **6.** a circuit that has some branches in parallel and some in series

_____ **7.** the value of a single resistor that could replace all resistors in a circuit without changing the current

_____ **8.** a device used to measure the current in part of a circuit

_____ **9.** a device used to measure the potential drop across some part of a circuit

_____ **10.** a device that detects small differences in current caused by an extra current path and opens the circuit

_____ **11.** a series circuit used to produce a voltage source from a higher-voltage battery

a. ammeter

b. circuit breaker

c. combination series-parallel circuit

d. equivalent resistance

e. fuse

f. ground-fault interrupter

g. parallel circuit

h. series circuit

i. short circuit

j. voltage divider

k. voltmeter

Section 23.1 ## Simple Circuits

In your textbook, read about currents in series circuits on pages 618–619.
Circle the letter of the choice that best completes the statement or answers the question.

1. The current is _____ a series circuit.

    a. higher at the beginning of   **c.** lower at the beginning of

    b. the same everywhere in   **d.** variable in

2. In an electric circuit, the increase in voltage provided by the generator or other energy source, ΔV_{source}, is equal to the _____ of voltage drops across the resistors.

    a. difference   **c.** sum

    b. product   **d.** average

3. Which of the following equations is *not* correct?

a. $I = \Delta V_{source}/(R_1 + R_2)$

c. $I = \Delta V_{source}/(R_1 + R_2 + R_3)$

b. $I = \Delta V_{source}/(R)$

d. $I = R_3 + (\Delta V_{source})/(R_1 + R_2)$

4. Which of the following equations computes the equivalent resistance for a series circuit with four resistors?

a. $R = R_1 + R_2 + R_3 + R_4$

c. $1/R = 1/R_1 + 1/R_2 + 1/R_3 + 1/R_4$

b. $R = R_1 \times R_2 \times R_3 \times R_4$

d. $R = (R_1 \times R_2)/(R_3 \times R_4)$

5. In a series circuit, the equivalent resistance is _____ any single resistance.

a. larger than

c. equal to

b. determined by

d. smaller than

6. If the battery voltage does not change, adding more devices in the series _____ the current.

a. sometimes decreases

c. sometimes increases

b. always decreases

d. always increases

7. To find the current through a series circuit, first calculate the _____.

a. voltage

c. power

b. equivalent resistance

d. equivalent voltage

In your textbook, read about voltage drops in series circuits on pages 618–619.
Answer the following questions. Use complete sentences.

8. Why must the net change in potential be zero as current moves through a circuit?

_____

_____

_____

9. How do you find the potential drop across an individual resistor?

_____
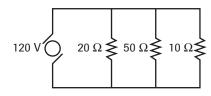
10. What type of circuit is used as a voltage divider?

_____

11. What is the purpose of a voltage divider?

_____

_____

12. What determines the resistance of a photoresistor?

_____

_____

_____

13. Name a device that employs the special qualities of a photoresistor. How does this device work?

_____

_____

_____

In your textbook, read about parallel circuits on pages 623–626.
Refer to the circuit diagram below to answer questions 14–18. Circle the letter of the choice that best answers each question.

14. What type of circuit does the diagram represent?

   a. a series circuit   **c.** a combination series-parallel circuit

   b. a parallel circuit   **d.** a tandem circuit

15. How many current paths are in this circuit?

   a. one   **c.** four

   b. three   **d.** five

16. How would you calculate the total current of this circuit?

   a. Find the average of the currents through each path.

   b. Subtract the currents through each path.

   c. Add the currents through each path.

   d. It is not possible to calculate total current for this circuit.

17. If the 10-Ω resistor were removed from the circuit, which of the following would not be true?

   a. The current through the 20-Ω resistor would be unchanged.

   b. The sum of the current in the branches of the circuit would change.

   c. The total current through the generator would change.

   d. The current through the 50-Ω resistor would change.

18. Which of the following is true for this circuit?

    a. The equivalent resistance of this circuit is smaller than 10 Ω.

    b. $R = R_1 + R_2 + R_3$

    c. $R = 1/R_1 + 1/R_2 + 1/R_3$

    d. $R = R_1 \times R_2 \times R_3$

Section 23.2   Applications of Circuits

In your textbook, read about safety devices on pages 627–628.
For each statement below, write **true** *or rewrite the italicized part to make the statement true.*

1. _____   When appliances are connected in parallel, each additional appliance placed in operation reduces the *equivalent resistance* in the circuit and causes more current to flow through the wires.

2. _____   The *length* of the metal in a fuse determines the amount of current that will melt the fuse and break the circuit.

3. _____   When a circuit breaker *opens*, it allows current to flow.

4. _____   Ground-fault interrupters can be used to detect differences in current caused by *an extra path* from the power source into the electric outlet and back to the source.

5. _____   Electric wiring at home uses only *series* circuits.

6. _____   Low resistance causes the current to be very *small* and may result in a short circuit.

In your textbook, read about combined series-parallel circuits on page 629.
Answer the following question. Use complete sentences.
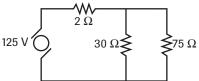
7. Describe the strategy you would use to calculate resistance in a combined series-parallel circuit.

_____

_____

_____

_____

_____

_____
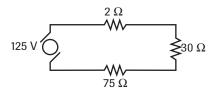
Circle the letter of the choice that best answers the following question.

8. Which diagram represents a combined series-parallel circuit in which a 30-Ω resistor and a 75-Ω resistor are connected in parallel to a 125-V source through a 2-Ω resistor in series?
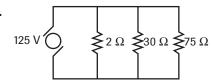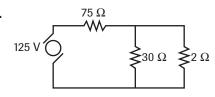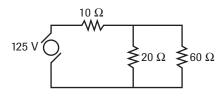
In your textbook, read about ammeters and voltmeters on page 631.
Refer to the circuit diagram below to answer questions 9a–c.

9. Redraw the circuit diagram according to the following directions.

   a. Insert an ammeter in the circuit that would measure the current of the entire circuit.

b. Insert an ammeter in the circuit that would measure the current that flows through the 60-Ω resistor.

c. Insert a voltmeter that would measure the voltage drop across the 10-Ω resistor.

Write the term that correctly completes the statement.

10. _____ A(n) _____ measures the voltage drop across a resistor.

11. _____ A(n) _____ measures current.

12. _____ The resistance of a voltmeter should be as _____ as possible so that it will change the current as little as possible.

13. _____ The resistance of an ammeter should be as _____ as possible so that it will change the current as little as possible.

14. _____ An ammeter is placed in _____ with the resistor if you want to measure the current through the resistor.

15. _____ A voltmeter should be connected in _____ with a resistor to measure the potential drop across that resistor.

16. _____ A(n) _____ always has low resistance and is connected in series.

17. _____ A voltmeter always has _____ resistance and is connected in _____ with the part of the circuit being measured.

18. _____ The result of connecting a(n) _____ across a resister is to lower the potential drop across it.

19. _____ The higher the _____ of a voltmeter, the smaller the voltage change.

20. _____ If you want to measure the current in a branch or part of a circuit, use a(n) _____.

CHAPTER
23 — Section 23-1 Quiz

1. What is equivalent resistance? How do you calculate it for a series circuit?

   _____

   _____

   _____

   _____

2. What is a voltage divider? How would a circuit designer create one?

   _____

   _____

   _____

   _____

   _____

3. Three resistors of 25 Ω, 30 Ω, and 40 Ω are in a series circuit with a 6.0-volt battery. What is the current in the circuit?

4. Three resistors of 25 Ω, 30 Ω, and 40 Ω are in a parallel circuit with a 6.0-volt battery. What is the current in the circuit?

CHAPTER
23   Section 23-2 Quiz

1. What is a short circuit? What is the relationship between a fuse and a short circuit?

_____

_____

_____

_____

_____

_____

2. What does an ammeter measure? What does a voltmeter measure? How would you insert each in a circuit?

_____

_____

_____

_____

3. Draw a series circuit with a 20.0-Ω resistor in series with a 30.0-Ω resistor and a 9.0-volt battery. Find the current in the circuit.

4. Draw a parallel circuit with a 9.0-volt battery, and a 20.0-Ω resistor in parallel with a 30.0-Ω resistor. Find the current in the circuit.
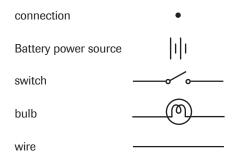
CHAPTER
23 — Reinforcement

Circuits and Computer Logic

Making schematic diagrams of circuits is a natural introduction to computer logic.

When creating circuits to perform specialized tasks, circuit designers make schematic diagrams that engineers use to build the circuit. Some schematic drawings look different but function identically. The following symbols are used in schematic drawings:

connection

Battery power source

switch

bulb

wire

1. Make a schematic diagram of a power source, two switches, and a bulb in a series.

2. Make a schematic diagram of a power source and two switches in parallel.

Computer communication eventually reduces to patterns of binary conditions. To make a decision, the computer checks the state of the circuit and takes one action if it encounters one state and a different action if it encounters another. An *and gate* instructs the computer to perform a given task when two or more conditions are all true. An *or gate* results when at least one of the conditions is true.

3. What type of circuit physically represents an *and gate*?

   _____

4. What type of circuit physically represents an *or gate*?

   _____

CHAPTER
23 Enrichment

Materials

- one battery
- three knife switches
- one button switch
- nine jumper wires
- one 6.3-V pigtail pilot lamp with leads and alligator clips
- one buzzer

Designing and Building an Alarm System

A burglar alarm system is designed to deter burglars or warn intended victims by sounding an alarm. Many systems are complex and expensive. However, a simple system can serve the same function. Using your knowledge of series and parallel circuits, you can design and build a burglar alarm that can generate audible or silent signals.

Procedure

Working in a group, discuss how you would create a circuit so that an audible alarm, silent alarm, or both would be set off at your discretion. Assume that a button switch is placed under a doormat just inside your front door. Be sure there is a way to turn off the entire system.

Results

The following symbols are used in schematic drawings:

Battery		Buzzer	
Switch		Wires	
Bulb		Connection	•

1. Create a schematic drawing of your alarm system.

2. Build a prototype of the system you designed on your schematic and verify that it functions as planned.

   a. List plan specifications for building the system.

   _____

   _____

   _____

   _____
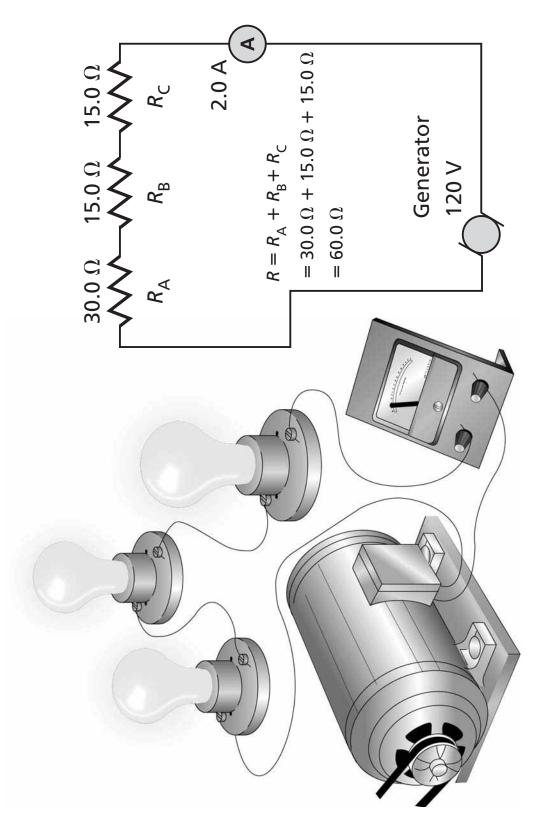
   b. List functions you want in your alarm system.

   _____

   _____

   _____

   _____

3. How would you categorize the type of circuit you designed? Explain your answer.

   _____

   _____

   _____

   _____

4. How would you categorize the buzzer and light in terms of electric devices?

   _____

   _____

5. If you redrew your schematic drawing, could you use a different symbol to depict these objects?

   _____

   _____

Series Circuit

R_A 30.0 Ω

R_B 15.0 Ω

R_C 15.0 Ω

A 2.0 A

$R = R_A + R_B + R_C$

$= 30.0\ \Omega + 15.0\ \Omega + 15.0\ \Omega$

$= 60.0\ \Omega$

Generator 120 V
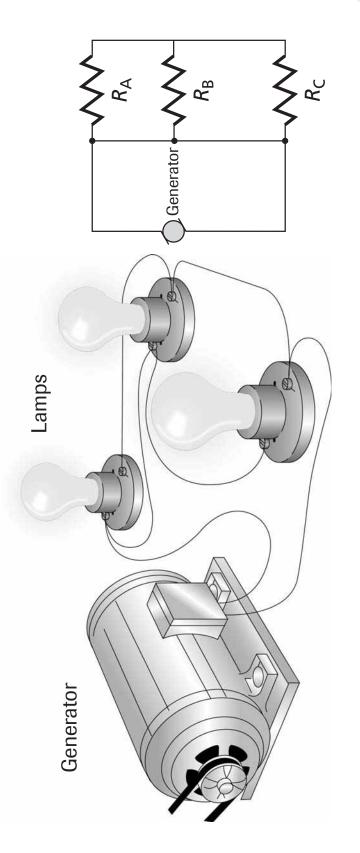
23 ___ Transparency 23-1 Worksheet

Series Circuit

1. From the schematic, how can you tell that this is a series circuit?

   _____

2. State the relationship between the individual resistances and the equivalent resistance in this circuit.

   _____

   _____

3. Calculate the current for this circuit.

4. For this circuit, what is the relationship between the overall potential difference and the potential drops across the individual resistors?

   _____

   _____

   _____

5. What is the voltage drop across R_A?

Parallel Circuit

R_A R_B R_C

Generator

Lamps

Generator
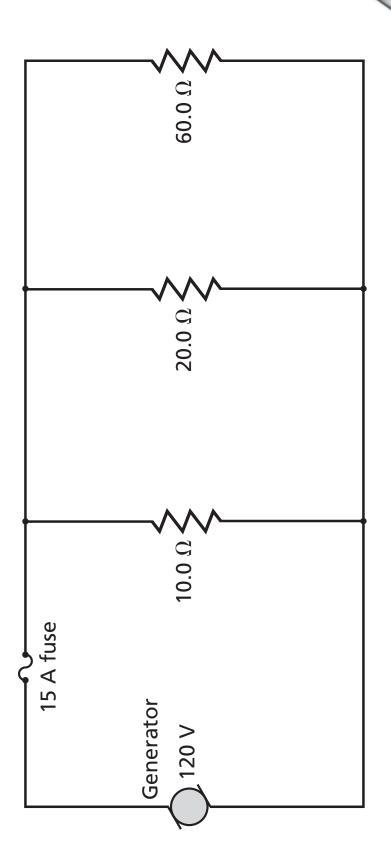
23 —— Transparency 23-2 Worksheet

Parallel Circuit

1. From the schematic, how can you tell this is a parallel circuit?

   _____

   _____

2. Through how many paths does the current flow in this circuit?

   _____

3. What is the equation for calculating the equivalent resistance of this circuit? Assuming values of 10.0 Ω, 5.0 Ω, and 2.0 Ω for R_A, R_B, and R_C respectively, calculate the equivalent resistance.

4. What is the relationship between the overall current and the current through the branches?

   _____

   _____

5. Assuming a resistance of 5.0 Ω and a potential difference of 60 V, what is the value of the current in R_B of this circuit?

Fuses
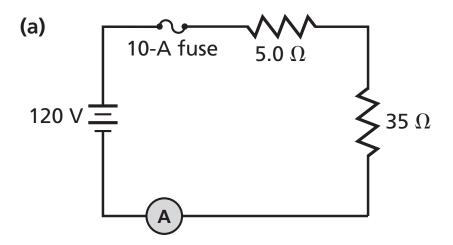
23 — Transparency 23-3 Worksheet
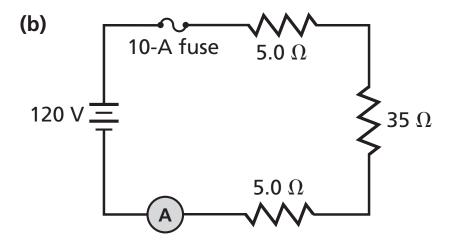
Fuses
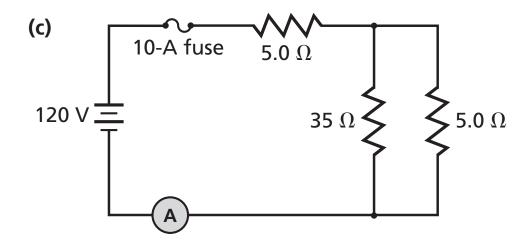
1. Are the resistors in this circuit connected in series or in parallel?

_____

2. What is the purpose of the fuse in this circuit?

_____

_____

3. What is the equivalent resistance of this circuit?

4. What is the total current traveling through this circuit?

5. How much of this current travels through the fuse? Explain your answer.

_____

_____

6. Will the fuse melt? Why or why not?

_____

_____

Combined Series/Parallel Circuits

(a)

10-A fuse   5.0 Ω

120 V

35 Ω

A

(b)

10-A fuse   5.0 Ω

120 V

35 Ω

5.0 Ω

A

(c)

10-A fuse   5.0 Ω

120 V

35 Ω   5.0 Ω

A

23 ___ **Transparency 23-4 Worksheet**

Combined Series/Parallel Circuits

1. In the circuit in Diagram **a**, what is the total resistance of the circuit?

2. In the circuit in Diagram **a**, what is the reading on the ammeter?

3. Will the fuse melt in the circuit in Diagram **a**? Explain your answer.

   _____

   _____

4. In the circuit in Diagram **b**, what is the total resistance of the circuit?

5. In the circuit in Diagram **b**, what is the reading on the ammeter?

6. Will the fuse melt in the circuit in Diagram **b**? Explain your answer.

   _____

   _____

7. In the circuit in Diagram **c**, what is the resistance of the parallel portion of the circuit? What is the total resistance of the circuit?

8. In the circuit in Diagram **c**, what is the reading on the ammeter?

9. Will the fuse melt in the circuit in Diagram **c**? Explain your answer.

   _____

   _____

10. Without changing the arrangement of the circuit (one resistor in series and two resistors in parallel), suggest a change that would prevent the fuse in Diagram **c** from melting.

    _____

    _____

CHAPTER
23 — Chapter Assessment

Series and Parallel Circuits
Understanding Physics Concepts

Circle the letter of the choice that best completes the statement or answers the question.

1. If four electric devices are connected in a series circuit, the number of current paths is equal to
   _____ .

   a. one   **c.** three

   b. two   **d.** four

2. As power is supplied to a circuit, _____ the circuit.

   a. resistance changes in   **c.** voltage divides in

   b. charges flow through   **d.** power escapes through

3. A series circuit contains four resistors. What is the equivalent resistance of the circuit?

   a. $4R$ **c.** $R/4$

   b. $R_1 + R_2 + R_3 + R_4$ **d.** $(R_1 + R_2 + R_3 + R_4)/4$

4. A series circuit has a 120-V generator, but requires a 60-V potential source. To achieve the desired
   potential, a _____ can be used.

   a. photoresistor   **c.** voltage divider

   b. sensor   **d.** semiconductor

5. If three resistors are connected in parallel, there are _____ current paths in the circuit.

   a. one   **c.** three

   b. two   **d.** four

6. In an electric circuit, _____ are switches that act as safety devices.

   a. fuses and circuit breakers   **c.** ammeters

   b. fuses and voltage dividers   **d.** combined circuits

For each statement below, write true *or* false.

_____ **7.** To measure the current through a resistor, an ammeter should be connected in series
with the resistor.

_____ **8.** The equivalent resistance of a parallel circuit is always less than the resistance of any
resistor in the circuit.

_____ **9.** A voltmeter should have a very low resistance so that it causes the largest possible
changes in currents and voltages in the circuit.

_____ **10.** The resistance of an ammeter should be as low as possible.

_____ **11.** To measure the current across a resistor, connect a voltmeter in parallel with the
resistor.

For each description on the left, write the letter of the matching item.

_____ **12.** the unit that describes the potential difference that comes out of a battery or generator

_____ **13.** *V/R*

_____ **14.** the instrument that measures current

_____ **15.** the depiction of lightbulbs or heating elements in a circuit diagram

_____ **16.** the unit that measures the number of volts per ampere

_____ **17.** the type of circuit in which the equivalent resistance is the sum of each resistor

_____ **18.** a safety device that stops current to a circuit

_____ **19.** a circuit in which there are several current paths

a. ammeter

b. current

c. ohm

d. parallel

e. resistors

f. fuse

g. series

h. volt

Write the term that correctly completes the statement.

20. _____ The increase in voltage provided by the generator or other energy source is equal to the sum of the _____ across the lamps in the circuit.

21. _____ The current produced in a given circuit hooked up to a given potential difference depends on the _____ of that circuit.

22. _____ In a parallel electric circuit, the potential difference across each path is _____ .

23. _____ In a parallel circuit, the _____ of the total resistance is the sum of the reciprocals of the individual resistances.

24. _____ Current is represented by the symbol _____ .

25. _____ A _____ can measure the potential lost by the current as it passes through a lightbulb.

26. _____ Current can only travel in a _____ circuit—one in which all of the switches are closed.

27. _____ In a parallel circuit, the total current is the _____ of the currents through each path.

28. _____ In a parallel circuit, _____ enable a user to turn on some of the electric devices and not others.

29. _____ A _____ , provided by a battery or a generator, is needed for a flow of charge to exist.

30. _____ To measure the potential drop across a resistor, a voltmeter is connected in _____ with the resistor.

Thinking Critically

Answer the following questions. Use complete sentences.

1. What happens to resistance when a resistor is added in parallel to a circuit that already has two resistors?

   _____

   _____

2. How is it possible to use more than one electric appliance at a time in a house?

   _____

   _____

   _____

3. A circuit has five identical resistors—A, B, C, D, and E. Resistors A, D, and E have the same potential difference across them. What kind of circuit is this? Give a reason for your answer.

   _____

   _____

   _____

4. What would happen to the current in a circuit if a voltmeter were substituted for an ammeter?

   _____

   _____

   _____

5. Why is a ground-fault interrupter often required by law for electric outlets in bathrooms and kitchens, but not in other rooms in a house?

   _____

   _____

   _____

   _____

6. Why does turning on additional appliances on the same circuit breaker increase the current through the wire?

   _____

   _____

   _____

   _____

7. What happens to line current when you connect more devices in series?

_____

_____

8. What happens to line current when you connect more devices in parallel?

_____

_____

9. What happens to a series current if one device fails?

_____

10. Two lamps are connected in parallel. If there are 6 V across one lamp, must there also be 6 V across the other lamp? Explain.

_____

_____

_____

11. What happens in a parallel circuit, when a new device is added?

_____

_____

12. Household circuits are normally wired in parallel.

    a. What would happen in a household if it were wired in series and one device failed?

    _____

    _____

    b. What would happen in that same household when additional devices were turned on?

    _____

    _____

13. Why are voltmeters designed to have a very high resistance?

_____

_____

_____

Applying Physics Knowledge

Answer the following questions. Show your calculations.
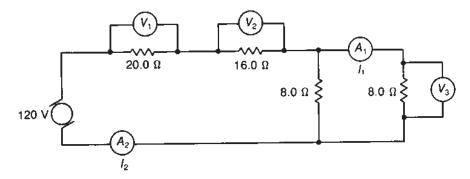
1. Two resistors of 3.0 Ω and 8.0 Ω are connected in series across a 9.0-V battery.

    a. Draw a schematic diagram.

    b. What is the equivalent resistance of the circuit?

    c. What is the current through the 3.0-Ω resistor?

    d. What is the current through the 8.0-Ω resistor?

    e. What is the voltage drop across each resistor?

2. A 15-Ω bell and an 8.0-Ω lamp are connected in parallel and placed across a potential difference of 42 V.

    a. Draw a schematic diagram.

    b. What is the equivalent resistance of the circuit?

    c. What is the current in the circuit?

    d. What is the current through each resistor?

    e. What is the voltage drop across each resistor?

Refer to the diagram below to answer questions 3–4. Show your calculations.

3. Find the reading of each ammeter and each voltmeter.

   a. What is the total current?

   b. What is the voltage drop across the 20-Ω resistor?

   c. What is the voltage drop across the 16-Ω resistor?

   d. What is the voltage drop across each 8-Ω resistor?

   e. What is the current at the branch measured by ammeter 1?

4. What is the power in watts used by each resistance in Question 3?

   a. the 20.0-Ω resistor

   b. the 16.0-Ω resistor

   c. the 8.0-Ω resistor

Magnetic Fields

CHAPTER
24   Mini Lab Worksheet

3-D Magnetic Fields

Tie a string to the middle of a nail so that the nail will hang horizontally. Put a small piece of tape around the string where it wraps around the nail so that the string will not slip. Insert the nail into a coil and apply a voltage to the coil. Turn off the power and remove the nail from the coil. Now hold the string to suspend the nail.

1. Predict how the nail will behave in the presence of a permanent magnet.

_____

_____

2. Test your prediction.

Analyze and Conclude

3. Explain what evidence you have that the nail became magnetized.

_____

_____

_____

4. Make a 3-D drawing that shows the magnetic field around the magnet.

CHAPTER
24 Physics Lab Worksheet

Materials

- large paper clips
- small paper clips
- steel BBs
- wire
- steel nail
- 6-V lantern batteries
- 9-V batteries
- DC power source

Creating an Electromagnet

An electromagnet uses the magnetic field generated by a current to magnetize a piece of metal. In this activity, you will construct an electromagnet and test one variable that you think might affect the strength of it.

Question

What is one variable that is related to the strength of an electromagnet?

Objectives

- ■ **Hypothesize** which variable might affect the strength of an electromagnet.
- ■ **Observe** the effects on an electromagnet's strength.
- ■ **Collect and organize data** comparing the chosen variable and magnet strength.
- ■ **Make and use graphs** to help identify a relationship between two variables.
- ■ **Analyze and conclude** what the effect is of the chosen variable on magnet strength.

24   Physics Lab Worksheet

Data Table	
Number of _____	**Number of Larger Paper Clips Picked Up**

Procedure

1. List the materials you will use to make your electromagnet.

2. List all the possible variables you think could affect the strength of an electromagnet.

3. Choose the one variable you will vary to determine whether it does, in fact, affect the strength of an electromagnet.

4. Determine a method to detect the strength of the magnetic field produced by the electromagnet.

5. Have your teacher approve your lists before continuing.

6. Write a brief procedure for your experiment. Be sure to include all the values for the variables you will be keeping constant.

7. Create a data table like the one above that displays the two quantities you will measure.

8. Build your electromagnet by using a nail and a length of wire. Wrap the wire around the nail. Be sure to leave several inches from both ends of the wire sticking out from your coil to allow attachment to the power source. *CAUTION: The end of the nail or wire may be sharp. Exercise care when handling these materials to avoid being cut or scraped.*

9. Have your teacher inspect your magnet before continuing.

10. Perform your experiment and record your data. *CAUTION: If you use BBs in your experiment, avoid possible injury by immediately picking up any BBs that fall to the floor.*

Analyze

1. **Make and Use Graphs** Create a graph showing the relationship between your two variables.

2. What were the variables that you attempted to control in this experiment? Were there any you were unable to control?

   _____

   _____

   _____

3. If you evaluated the strength of the electromagnet by the amount of material it could pick up, how did you try to control any error from the magnet attracting only whole numbers of objects?

   _____

   _____

   _____

Conclude and Apply

1. What is the relationship between your chosen variable and the strength of a magnet?

   _____

   _____

   _____

2. What variables did other students in your class find that also affected the strength of an electromagnet?

   _____

   _____

   _____

3. Were there any variables, by any group, that were found not to affect the strength of the electromagnet?

   _____

   _____

   _____

Going Further

1. Compare the various variables students found that affected magnet strength. Did any of the variables appear to greatly increase strength without much change in the independent variable? If so, which ones?

_____

_____

_____

2. If you wanted to increase magnet strength, which method seems the most cost effective? Explain.

_____

_____

_____

3. If you need to easily vary the strength of an electromagnet, how would you suggest that be done?

_____

_____

Real-World Physics

1. If you needed to create a stronger electromagnet for use in a small space, such as inside a laptop computer, what method would you use to increase the electromagnetic strength, given the size constraints?

_____

_____

2. Some buildings have electromagnets to hold fire doors open when the building is occupied. These magnets are mounted to the wall, like a door stop, behind the door. Thinking about the actions a fire alarm system would need to perform to control a fire, what is the advantage of using a system like this to hold the doors? How might a system like this be an advantage, or a disadvantage, in the event of a natural disaster?

_____

_____

3. Some electric bells work by having an arm strike the side of a metal dome-shaped bell. How might an electromagnet be used to make this bell work? How might the bell be wired to allow the arm to strike repeatedly (continual ringing) until the power supply is removed?

_____

_____

_____

_____

Physics **nline**

To find out more about magnetic fields, visit the
Web site: **physicspp.com**

CHAPTER
24 — Study Guide

Magnetic Fields

Vocabulary Review

Write the term that correctly completes the statement. Use each term once.

armature	first right-hand rule	polarized
domain	galvanometer	second right-hand rule
electric motor	magnetic field	solenoid
electromagnet	magnetic flux	third right-hand rule

1. _____ A long coil of wire that contains many loops is called a(n) _____.

2. _____ A group of neighboring atoms whose electrons' magnetic fields all align in the same direction is called a(n) _____.

3. _____ _____ exist in a region of space where a magnetic force occurs.

4. _____ The _____ can be used to determine the direction of a field produced by an electromagnet relative to the flow of a conventional current.

5. _____ A(n) _____ is a device that converts electric energy into rotational kinetic energy.

6. _____ The _____ can be used to determine the direction of the force on a current-carrying wire in a magnetic field.

7. _____ The _____ can be used to determine the direction of a magnetic field relative to the direction of a conventional current.

8. _____ The number of magnetic field lines that pass through a surface is called _____.

9. _____ A magnet created when a current flows through a coil of wire is a(n) _____.

10. _____ A(n) _____ is a device used to measure very small currents.

11. _____ A magnet is _____, which means that it has two distinct and opposite ends.

12. _____ A(n) _____ is a wire coil in an electric motor made of many loops mounted on a shaft or axle.

Section 24.1 **Magnets: Permanent and Temporary**
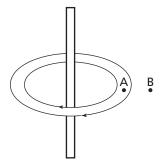
In your textbook, read about general properties of magnets on pages 644–645.
For each statement below, write **true** *or rewrite the italicized part to make the statement true.*
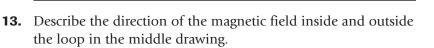
1. _____ When a magnet is allowed to swing freely, it comes to rest aligned in an *east–west* direction.

2. _____ A *compass* is a small magnet mounted so that it is free to turn.

3. _____ Like poles *attract* each other.

4. _____ Magnets *do not always* have two opposite magnetic poles.

5. _____ If Earth is considered to be a giant magnet, the south pole of the magnet is near Earth's *geographic north pole*.

6. _____ Many permanent magnets are made of *pure iron*.

In your textbook, read about magnetic fields around permanent magnets on pages 645–647.
Answer the following questions. Use complete sentences.

7. How could you show the magnetic field around a magnet?

_____

_____

_____

8. What does *magnetic flux* mean in terms of both magnetic field lines and magnetic field strength?

_____

_____

_____

9. Describe the direction and shape of the magnetic field lines of a bar magnet.

_____

_____

10. Describe three things that happen when a sample made of iron, cobalt, or nickel is placed in the magnetic field of a permanent magnet.

_____

_____

_____
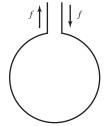
In your textbook, read about electromagnetism on pages 648–649.
Refer to the figures at right to answer questions 11–15. Use complete sentences.

11. What is the direction of the conventional current in the top figure?

_____

_____
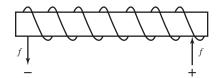
12. Is the magnetic field stronger at Point A or Point B?

_____

_____

13. Describe the direction of the magnetic field inside and outside the loop in the middle drawing.

_____

_____

14. In the bottom drawing of an electromagnet, which end is the magnetic north pole?

_____

_____

15. What are three ways you can increase the strength of the magnetic field around an electromagnet?

_____

_____

In your textbook, read about magnetic materials at the microscopic level on pages 650–651.
For each of the statements below, write **true** *or* **false.**

_____ **16.** The magnetic fields of the electrons in a group of neighboring atoms cannot be combined.

_____ **17.** When a piece of iron is not in a magnetic field, the domains point in random directions.

_____ **18.** In permanent magnets, the domains point in random directions.

_____ **19.** The material on magnetic recording tape allows the domains to keep their alignments until a magnetic field is applied that is strong enough to change them.

_____ **20.** The direction of magnetization in rocks on the seafloor varies, indicating that the north and south poles of Earth have moved many times.

Section 24.2 Forces Caused by Magnetic Fields

In your textbook, read about forces on currents in magnetic fields on pages 652–653.

Circle the letter of the choice that best completes the statement.

1. The force on a current-carrying wire in a magnetic field is _____ both the direction of the magnetic field and the direction of current.

   a. parallel to   **c.** opposite

   b. at right angles to   **d.** independent of

2. The magnitude of the force on a current-carrying wire in a magnetic field is proportional to _____.

   a. the strength of the field, the current in the wire, and the length of the wire in the magnetic field

   b. the strength of the field only

   c. the strength of the field and the current in the wire

   d. the strength of the field, the current in the wire, and the voltage in the wire

3. The strength of a magnetic field is measured in _____.

   a. newtons   **c.** amperes

   b. teslas   **d.** volts
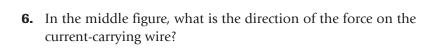
4. The direction of Earth's magnetic field is toward the _____.

   a. equator   **c.** south magnetic pole
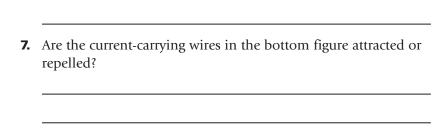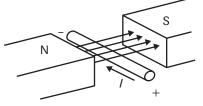
   b. north magnetic pole **d.** surface
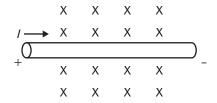
Refer to the figures at right to answer questions 5–7. Use complete sentences.
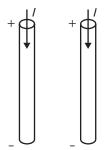
5. In the top figure, what is the direction of the force on the current-carrying wire?

   _____

   _____

6. In the middle figure, what is the direction of the force on the current-carrying wire?

   _____

   _____

7. Are the current-carrying wires in the bottom figure attracted or repelled?

   _____

   _____

In your textbook, read about loudspeakers on page 653.
For each statement below, write **true** *or* **false.**

_____ **8.** The force on a current-carrying wire in a magnetic field is used in a loudspeaker.

_____ **9.** The force exerted on the coil of wire in a magnetic field in a loudspeaker pushes the coil into or out of the field, depending on the magnitude of the current.

_____ **10.** A loudspeaker changes electrical energy directly into sound energy.

_____ **11.** The amplifier that drives a loudspeaker sends a current through a coil of wire mounted on a paper cone.

_____ **12.** The motion of the coil in a loudspeaker causes the cone to vibrate, which creates sound waves.

In your textbook, read about galvanometers on pages 655–656.
Write the term that correctly completes the statement. Use each term once.

current	**loop**	**parallel**	**torque**
direction	**magnetic fields**	**proportional**	**voltmeter**
down	**multiplier**	**series**	**wire**
galvanometers			

(**13**) _____ that exert forces on a loop of wire carrying a current can be used

to measure very small currents. A small loop of (**14**) _____ that is carrying a

current is placed in the strong magnetic field of a permanent magnet. The current passing through

the (**15**) _____ goes in one end and out the other. The

(**16**) _____ of the force on the wire resulting from the magnetic field

can be determined by using the third right-hand rule. One side of the loop is forced

(**17**) _____; the other side is forced up. The resulting

(**18**) _____ rotates the loop. The magnitude of the torque acting on the loop

is proportional to the magnitude of the (**19**) _____. This principle is used in

(**20**) _____ to measure small currents. A small spring in a galvanometer

exerts a torque that opposes the torque resulting from the current. Thus the amount of torque is

(**21**) _____ to the current. A galvanometer can be used as a(n)

(**22**) _____ or an ammeter. A galvanometer can be converted to an ammeter by

connecting it in (**23**) _____ with a resistor that has a resistance smaller than

that of the galvanometer. To convert a galvanometer to a voltmeter, the galvanometer is connected in

(**24**) _____ with a resistor called a (**25**) _____.

In your textbook, read about the force on a single charged particle on page 657.
Answer the following questions. Use complete sentences.

26. How do pictures form on the screen of a cathode-ray tube in a computer monitor or television set?

_____

_____

_____

_____

_____

_____

27. The force produced by a magnetic field on a single electron depends on what three factors?

_____

_____

_____

28. Why is the direction of the force on an electron in a magnetic field opposite the direction given by the third right-hand rule?

_____

_____

_____

In your textbook, read about storing information with magnetic media on page 659.
Answer the following questions. Use complete sentences.

29. How are bits stored on computer storage disks?

_____

_____

_____

_____

30. How are data retrieved from a computer storage disk?

_____

_____

_____

_____

CHAPTER
24 ___ **Section 24-1 Quiz**

1. Describe two general properties of magnets.

    _____

    _____

    _____

    _____

2. Why do magnets attract or repel each other even when they are held apart?

    _____

    _____

    _____

3. What causes electromagnetism?

    _____

    _____

    _____

    _____

4. What causes magnetism at a microscopic level?

    _____

    _____

    _____

    _____

    _____

5. How does the strength of the magnetic field that is 1 cm from a current-carrying wire compare
    with the strength of the magnetic field that is 4 cm from the wire?

    _____

    _____

    _____

CHAPTER
24 Section 24-2 Quiz

1. How can a galvanometer be used as an ammeter? As a voltmeter?

   _____

   _____

   _____

   _____

   _____

2. Do charged particles need to be confined to a wire? Why or why not? Give an example that supports your answer.

   _____

   _____

   _____

   _____

3. A wire is at right angles to a uniform magnetic field that has a magnetic induction of 0.55 T. The current through the wire is 7.5 A, and 23.0 cm of the wire is in the field. What is the force acting on the wire?

4. A high-speed electron travels at right angles to a magnetic field that has an induction of 1.77 T. The electron is traveling at 2.83×10^7 m/s. What is the force acting on the electron?

CHAPTER
24 Reinforcement

Materials

👓 🧤
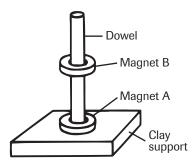
- two ceramic disk magnets with holes in the center
- short wood dowel or pencil
- 25 identical metal washers
- metric ruler
- modeling clay
- balance

Determining Magnetic Force

Procedure

1. Find and record the mass of one of the magnets. This will be Magnet B.

2. Find the mass of ten washers, divide the mass by 10 to find the average mass of one washer, and record the mass.

3. Form a base using modeling clay, and stand the dowel or pencil in it, as shown in the figure.

4. Place Magnet A over the dowel so it rests on the clay.

5. Place Magnet B over the dowel. If it touches Magnet A, remove it, turn it over, and replace it on the dowel.

6. Measure the distance between the magnets.

7. Add washers one at a time until the distance between the magnets is half the original distance. Record the number of washers added.

8. Add more washers until the distance between the magnets is one-third the original distance. Record the total number of washers added.

Dowel
Magnet B
Magnet A
Clay support

Mass of Magnet B (g)	
Average mass of one washer (g)	
Number of washers added at 1/2 distance	
Number of washers added at 1/3 distance	

Results

1. Why does Magnet B float above Magnet A?

_____

_____

2. The magnetic force upward on Magnet B is equal to the downward force of gravity. Calculate the magnitude of the magnetic force.

3. When you added washers to reduce the distance between the magnets to one-half, what was the new magnetic force?

4. When you added more washers to reduce the distance between the magnets to one-third, what was the new magnetic force?

5. What is the relationship between the distance between the magnets and the magnetic force between them?

_____

_____

_____

CHAPTER
24 Enrichment

Materials

⬛ 🔌 🥽 🧤

- bell wire
- test tube
- masking tape
- ring stand and two clamps
- variable DC source
- DC ammeter
- switch
- iron nail
- paper clip
- pliers
- long, thin rubber band
- metric ruler

A Simple Meter
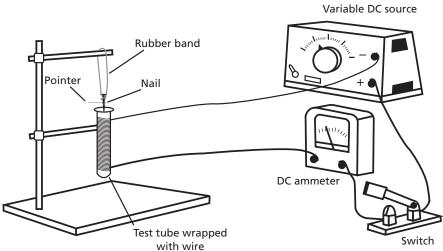
Procedure

A simple meter is illustrated in the figure below. To construct the meter:

1. Wind 100 to 150 turns of bell wire around a test tube to form a coil.
2. Secure the wire with masking tape.
3. Mount the completed coil on the ring stand with a clamp.
4. Connect the wires leading from the coil to form a series circuit with the variable DC source, ammeter, and switch, as shown in the figure.
5. Straighten a paper clip and wrap it tightly around the top of a nail. Make one end of the paper clip stick out to form a pointer. You may need a pair of pliers to clamp the pointer firmly to the nail.
6. Attach the rubber band to the head of the nail. Use the rubber band to suspend the nail from a clamp. The tip of the nail should be just inside the top of the coil.

To calibrate the meter:

1. Make sure the nail is free to move within the test tube.
2. Use a metric ruler to measure the height of the pointer above the ring stand base when no current is flowing in the coil.
3. Close the switch and adjust the variable DC source to achieve a reading of 1 A on the ammeter.
4. Measure the height of the new pointer position.
5. Repeat this procedure, using 1-A increases in current until you have an ammeter reading of 5 A. If the deflections of your nail are too small, set the nail a little lower in the tube, or use a thinner rubber band to suspend the nail. You may wish to achieve higher ammeter readings, but be careful not to let the coil get too hot.

Variable DC source
Rubber band
Pointer
Nail
DC ammeter
Test tube wrapped with wire
Switch
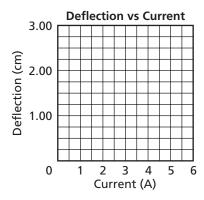
Use a metric ruler to determine how far the pointer deflected from its rest position for each of the ampere settings on the variable DC source. Record your data in the table.

Results

Current (A)	Height (cm)	Deflection (cm)
0		0.00
1		
2		
3		
4		
5		

1. Use electromagnetic principles to explain how your meter works.

_____

_____

2. In the space provided, create a graph of deflection versus current. What kind of relationship does the graph show?

Deflection vs Current
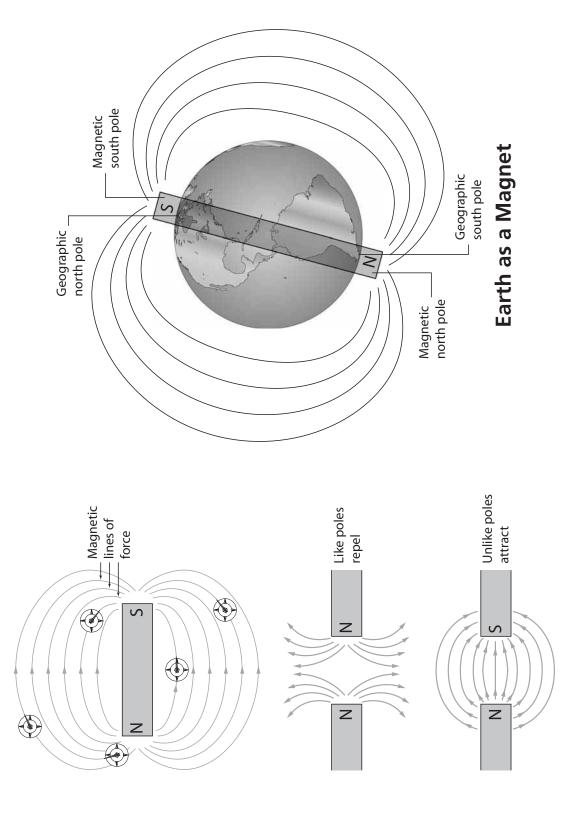
3. What does the relationship shown on the graph suggest about force versus current in electromagnets?

_____

4. Using the graph, predict the pointer deflections for 1.5-A, 2.6-A, and 3.25-A currents.

_____

5. Test your predictions using the actual currents listed in Question 5. How do the results compare with the predictions?

_____

6. How could you make your current meter more sensitive (that is, capable of having a larger deflection for each ampere increase of current)?

_____

_____

Magnetic Lines of Force

Magnetic
south pole

Geographic
north pole

Magnetic
north pole

Geographic
south pole

Earth as a Magnet

Magnetic
lines of
force

S

N

Like poles
repel

N

N

Unlike poles
attract

S

N
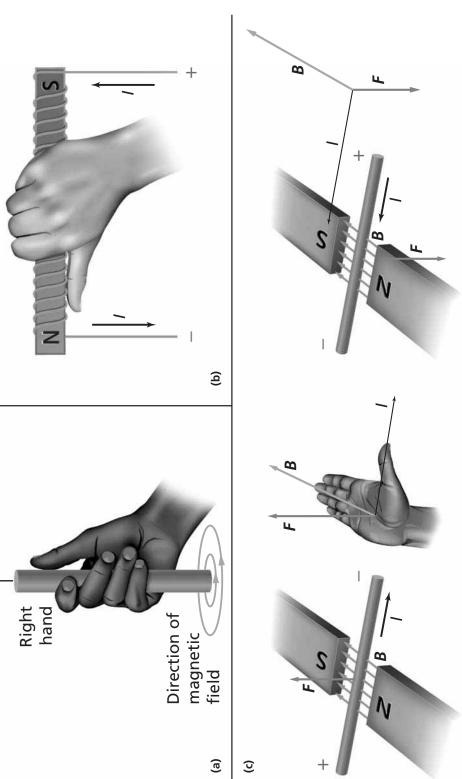
24 — Transparency 24-1 Worksheet

Magnetic Lines of Force

1. What do the compasses in the drawing of the single magnet indicate?

   _____

   _____

2. What are the lines surrounding the magnets? What do the lines indicate?

   _____

   _____

3. What does the number of magnetic field lines indicate?

   _____

   _____

4. Where is the magnetic flux most concentrated? What does this indicate?

   _____

   _____

   _____

5. What are the rules that describe how magnets interact with each other?

   _____

6. Where is the north pole of the Earth magnet?

   _____

7. To which end of the Earth magnet does the north pole of a compass point?

   _____

   _____

8. Where is Earth's magnetic field strongest?

   _____

Right-Hand Rules

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(a)

(b)

(c)
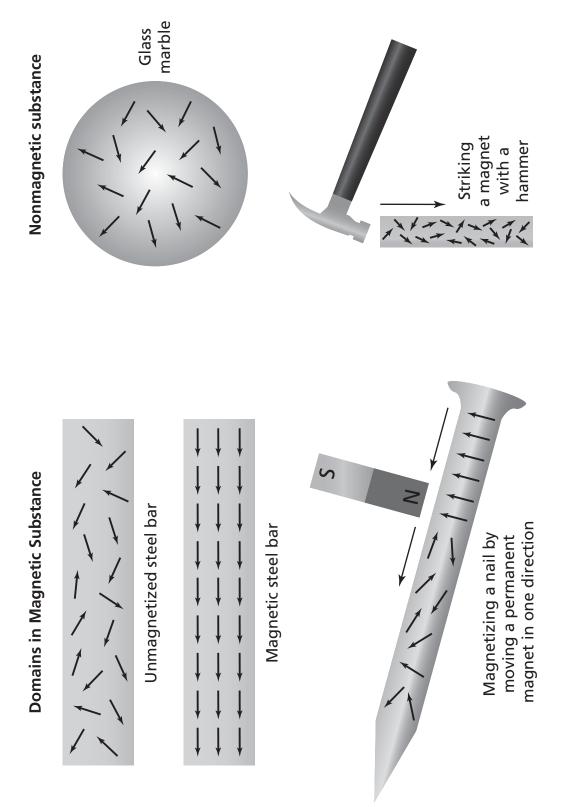
24 ___ **Transparency 24-2 Worksheet**

Right-Hand Rules

1. Which rule is represented in **Figure a?**

   _____

2. In which direction does the thumb point?

   _____

3. In which direction do the fingers point?

   _____

4. What type of magnet is shown in **Figure b?**

   _____

5. What effect does the iron core inside the coil have on the magnet?

   _____

6. What rule is represented in Figure b?

   _____

7. Using the second right-hand rule, describe how the north pole of the magnet is indicated.

   _____

8. Using the second right-hand rule, describe how the direction of conventional current flow is indicated.

   _____

9. What rule is represented in **Figure c?**

   _____

10. In Figure c, which direction is represented by the fingers of the right hand? By the right thumb?

    _____

    _____

    _____

11. How is the direction of the force acting on the wire represented?

    _____

    _____

12. What effect does reversing the direction of current flow have on the direction of the force acting on the wire?

    _____

Magnetic Domains

Nonmagnetic substance

Glass marble

Striking a magnet with a hammer

Domains in Magnetic Substance

Unmagnetized steel bar

Magnetic steel bar

Magnetizing a nail by moving a permanent magnet in one direction

S

N

24 ⎯⎯ Transparency 24-3 Worksheet

Magnetic Domains

1. What is a magnetic domain?

_____

_____

2. How are the unmagnetized steel bar and the glass marble similar?

_____

3. How are the unmagnetized steel bar and the glass marble different?

_____

4. How could you magnetize the unmagnetized steel bar or the nail?

_____

_____

5. What happens at the microscopic level when a steel bar or nail is magnetized?

_____

_____

6. What can happen if a magnet is dropped or struck with a hammer?

_____

_____

7. What is the difference between a temporary magnet and a permanent magnet?

_____

_____

_____

_____

MagLev Trains

Propulsion System

Alternating magnetic fields push/pull the train forward.

Guideway

Train

Propulsion magnets

Normal conducting coils

Super conducting coils

Levitation magnets
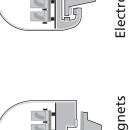
Levitation Techniques

Electrodynamic

Electromagnets on the guideway levitate the car.

Electromagnetic
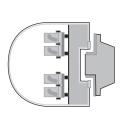
Electromagnets on the cars lift them.

Inductrack

Permanent magnets levitate over passive coils.

24 ⎯ Transparency 24-4 Worksheet

Maglev Trains

1. What is the term *maglev train* short for?

_____

2. What basic principle is used to levitate a maglev train?

_____

_____

_____

_____

3. What are three levitation techniques used for maglev trains? How does each technique work?

_____

_____

_____

_____

_____

_____

_____

_____

4. How does the propulsion system of a maglev train work?

_____

5. Maglev trains are expected to be able to reach speeds of 500 km/h, which is much faster than conventional trains. Why do you think this is true?

_____

_____

_____

6. Look at the shape of the maglev train. What is another reason for the high speed of maglev trains?

_____

_____

CHAPTER

24 — Chapter Assessment

Magnetic Fields
Understanding Physics Concepts

Circle the letter of the choice that best completes the statement.

1. An object that is magnetic has _____.

   a. only a south-seeking pole

   b. only an east-seeking pole

   c. an east-seeking pole and a west-seeking pole

   d. a north-seeking pole and a south-seeking pole

2. The magnitude of the current in a wire is _____ to the magnetic field around the wire.

   a. proportional

   b. inversely proportional

   c. equal

   d. parallel

3. Increasing the number of loops in an electromagnet causes the strength of the magnetic field to _____.

   a. increase

   b. decrease

   c. remain the same

   d. double

4. In a magnetic material, the _____ act like tiny electromagnets.

   a. atoms

   b. electrons

   c. protons

   d. neutrons

5. The magnetic force on a current-carrying wire in a magnetic field is _____ the direction of the current.

   a. opposite

   b. parallel to

   c. perpendicular to

   d. the same as

For each statement below, write true *or rewrite the italicized part to make the statement true.*

6. _____ The *magnitude* of the magnetic force on a current-carrying wire depends on the strength of the magnetic field, the current in the wire, and the length of wire in the magnetic field.

7. _____ When two parallel wires carry currents in opposite directions, their magnetic fields *attract* each other.

8. _____ A device used to measure very small electric currents is *a voltmeter*.

9. _____ In an electric motor, current is reversed every *complete turn*.

10. _____ The speed of an electric motor can be controlled by *varying* the current flow.

24 ⎯ Chapter Assessment

Answer the following questions. Use complete sentences.

11. Can you create separate north and south poles by breaking a magnet in half? Explain your answer.

_____

_____

12. What are many permanent magnets made out of?

_____

_____

13. How is magnetism similar to gravity?

_____

_____

14. Describe the general shape of a magnetic field line.

_____

_____

_____

_____

15. What happens when you pass a magnetic compass over a current-carrying wire? Explain.

_____

_____

16. What did Faraday discover about the force on a current-carrying wire?

_____

_____

_____

17. How is an electric motor different from a galvanometer?

_____

_____

_____

18. What do seafloor rocks tell scientists about the history of Earth's magnetic field?

_____

_____

Thinking Critically

Answer the following questions. Show your calculations.

1. A wire carries a current of 6.0 A. The wire is at right angles to a uniform magnetic field, and 0.80 m of the wire is in the field. The force on the wire is 0.62 N. What is the strength of the magnetic field?

2. A wire is at right angles to a uniform magnetic field with magnetic induction of 0.400 T. The current through the wire is 4.00 A. What is the force that acts on the wire when 60.0 cm is in the field?

3. A wire carries a current of 12 A. The wire is at right angles to a uniform magnetic field that exerts a force of 0.50 N on the wire when 2.0 m of the wire is in the field. What is the strength of the magnetic field?

4. A wire is at right angles to a magnetic field that exerts a force of 2.4 N on the wire. A current of 8.6 A flows through the wire. The induction of the magnetic field is 0.66 T. What length of wire is in the field?

5. A high-speed electron travels at right angles to a magnetic field that has an induction of 0.420 T. The electron is traveling at 3.46×10^7 m/s. What is the force acting on the electron?

24 Chapter Assessment

Answer the following questions. Use complete sentences.

6. If all electrons create magnetic fields, why are all materials not magnetic?

_____

_____

_____

7. How are the forces between charges similar to the forces between magnetic poles?

_____

_____

_____

8. Suppose you have two bar magnets. On only one of the magnets, the north and south poles are labeled. How could you identify the north and south poles on the unlabeled magnet?

_____

_____

_____

9. An electrical wire carries current in a straight line from east to west. What is the direction of the resulting magnetic field above the wire? What is the direction of the field below the wire?

_____

_____

_____

10. If an electromagnet is used to pick up several small metal objects and the current is then turned off, what happens?

_____

_____

_____

11. If a permanent magnet is dropped or struck with a hammer, it may lose its magnetism. Why?

_____

_____

_____

Physics: Principles and Problems

Applying Physics Knowledge

Answer the following questions. Use complete sentences.

1. What causes the aurora borealis?

_____

_____

_____

_____

_____

_____

2. How could you use a battery, a switch, several lengths of wire, and a large iron nail to build an electromagnet?

_____

_____

_____

_____

_____

_____

3. How does the electromagnet in Question 2 work? How does the nail make the electromagnet stronger?

_____

_____

_____

_____

_____

_____

4. What else could you do to make the electromagnet stronger?

_____

_____

5. Suppose you are designing an amplifier and loudspeaker system to use at a rock concert. You want to make it as loud as possible. How can you design the system to maximize the volume? Explain your answer.

    _____

    _____

    _____

    _____

    _____

    _____

Answer the following questions. Show your calculations.

6. A section of wires and resistors in a circuit has a total resistance of 6.0 W and a potential difference of 120 V. If 0.40 m of the wire is placed in a uniform magnetic field at right angles to the field, the force on the wire is 0.50 N. What is the strength of the magnetic field?

7. A proton travels at 1.0×10^5 m/s, perpendicular to a uniform magnetic field of 5.5×10^{-5} T. What is the magnitude of the acceleration of the proton?

Electromagnetic Induction

CHAPTER
25 — Mini Lab Worksheet

Motor and Generator 👓🔧

Motors and generators differ, mainly in the way they convert energy—electric to mechanical compared to mechanical to electric.

1. Make a series circuit with an efficient DC motor, a miniature lamp, and an ammeter.

2. Rotate the handle, or motor shaft, to try to light the lamp.

Analyze and Conclude

3. What happens if you vary the speed at which you rotate the handle?

_____

_____

_____

_____

4. **Predict** what will happen if you connect your motor to a second motor.

_____

_____

_____

_____

CHAPTER
25 — Physics Lab Worksheet

Materials

- primary and secondary coil apparatus
- small AC power supply
- AC voltmeter
- DC power supply (0-6V, 0-5A)
- connecting wires with alligator clips
- small lightbulb with wires

Induction and Transformers
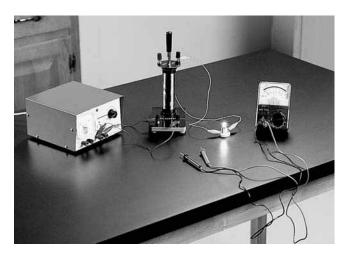
A transformer is an electric device without any moving components. It is made of two electric circuits interlinked by a magnetic field. A transformer is used to increase or decrease an AC potential difference, which often is called *voltage*. Transformers can be found everywhere. Every electronic device that plugs into your household electric circuits incorporates a transformer, usually to lower the voltage going to the device. Televisions that have standard cathode-ray picture tubes incorporate high-voltage transformers, which raise the standard household voltage to tens of thousands of volts. This accelerates electrons from the rear of the tube to the screen. In this experiment, you will use two coils with a removable iron core. One coil is called the primary coil, the other the secondary coil. When an AC voltage is applied to the primary coil, the changing magnetic field induces a current, and thus, a voltage in the secondary coil. This induced voltage is expressed by $V_s/V_p = N_s/N_p$, where N refers to the number of turns in the coils.
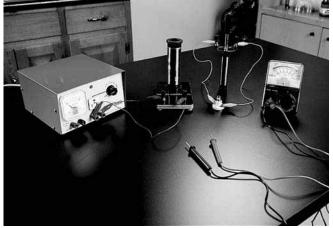
Question

What is the relationship between voltages in the two coils of a transformer?

Objectives

- **Describe** how a transformer works.
- **Observe** the effect of DC voltage on a transformer.
- **Observe** the effect of AC voltage on a transformer.

Data Table	
Number of primary coils	
Number of secondary coils	
Step 3 observation	
Step 4 observation	
Step 5 observation	
Step 6 observation	
Step 7 coil volts (V)	
Step 8 observation	
Step 9 iron core	

Procedure

1. Estimate the number of coils of wire on the primary and secondary coils. Do this by counting the number of coils in 1 cm and multiplying by the coil's length in centimeters. The primary coil has one layer. The secondary coil has two layers of wire, so double the value for it. Record your results in the data table.

2. Place a small lightbulb across the contacts of the secondary coil. Carefully place the secondary coil into the primary coil. Slowly insert the iron core into the center of the secondary coil.

3. Attach two wires to the output of the DC power supply. Attach the positive wire from the power supply to one of the primary connections. Turn the power supply to nearly its maximum output setting. Holding the free end of the wire attached to the negative connection, gently tap its end to the other primary coil connection. Observe the area where you touch the wire to the connection. Record your observations in the data table.

4. Observe the lightbulb while you are gently tapping the connection. What happens as the wire makes contact and then breaks the electric contact? Record your observation in the data table.

5. Hold the negative wire to the primary coil connection for 5 s and observe the lightbulb. Record your observation in the data table.

6. Disconnect the DC power supply and put it away while leaving the small lightbulb attached to the secondary coil. Attach the AC power supply to the two primary coil connections. Plug in the AC power supply and observe the lightbulb. Record your observations in the data table.

7. Select the AC scale for your voltmeter. Insert the probes into the voltmeter and carefully touch them to the primary coil and measure the applied voltage. Move the probe from the primary coil and measure the secondary coil voltage. Record both readings in the data table.

8. Repeat step 7, but slowly remove the iron core from the secondary coil. What happens to the lightbulb? Measure both primary and secondary coil voltages while the core is being removed. Record your observations in the data table.

9. Carefully feel the iron core. What is your observation? Record it in the data table.

Analyze

1. Calculate the ratio of N_s/N_p from your data.

2. Calculate the ratio of V_s/V_p from your data.

3. **Interpret Data** How do the ratios N_s/N_p and V_s/V_p compare?

    _____

    _____

    _____

4. **Recognize Cause and Effect** Based on the data for step 7, is this transformer a step-up or a step-down transformer? What evidence do you have to support this conclusion?

    _____

    _____

    _____

Conclude and Apply

1. **Infer** How can you explain your observation of the lightbulb in step 4?

    _____

    _____

    _____

2. Infer How can you explain the phenomena you observed at the negative connection of the primary coil in step 3?

_____

_____

_____

3. Infer How can you explain your observations of the primary and the secondary coil voltages as you removed the iron core in step 8?

_____

_____

_____

4. Explain Explain the temperature of the iron core you observed in step 9.

_____

_____

_____

Going Further

Why does the transformer work only with alternating and not direct current?

_____

_____

_____

Real-World Physics

Discuss the use of transformers to assist in the delivery of electricity from the power plant to your home.

_____

_____

_____

Physics nline

To find out more about induction and transformers, visit the Web site: **physicspp.com**

CHAPTER
25 ___ Study Guide

Electromagnetic Induction

Vocabulary Review

For each definition below, write the correct term.

average power	fourth right-hand rule	step-down transformer
effective voltage	Lenz's law	step-up transformer
electromagnetic induction	mutual inductance	
electromotive force	primary coil	

1. _____ the statement that an induced current is always produced in a direction such that the resulting magnetic field opposes the change in the magnetic field that is causing the induced current

2. _____ the potential difference that is produced by electromotive induction

3. _____ a transformer with a lower voltage across the secondary circuit than across the primary circuit

4. _____ the effect that occurs in a transformer when a varying magnetic field created in the primary coil is carried through the iron core to the secondary coil, where the varying field induces a varying *EMF*

5. _____ another term for RMS (root mean square) voltage

6. _____ statement that if you hold your hand so that your thumb points in the direction the wire is moving, and your fingers point in the direction of the magnetic field, then your palm will point in the direction of the conventional (positive) current

7. _____ the generation of current through a circuit due to the relative motion between a wire and a magnetic field

8. _____ a transformer with higher voltage across the secondary circuit than across the primary circuit

9. _____ an insulated transformer coil that creates a varying magnetic field when it is connected to an alternating-current voltage source

10. _____ half of the maximum power generated by a generator

Section 25.1 **Electric Current from Changing Magnetic Fields**

In your textbook, read about electric current from charging magnetic fields on pages 671–678.

Circle the letter of the choice that best completes the statement.

1. To generate a current in a wire in a magnetic field, _____.

   a. the conductor must move through the magnetic field while the magnetic field remains stationary

   b. the magnetic field must move past the conductor while the conductor remains stationary

   c. there must be relative movement between the wire and the magnetic field

   d. there must be a battery connected to the wire

2. If a wire moves through a magnetic field at an angle to the field, only the component of the wire's velocity that is _____ generates *EMF*.

   a. negative

   b. parallel to the direction of the magnetic field

   c. perpendicular to the direction of the magnetic field

   d. positive

3. When a wire is held stationary or moved _____ to a magnetic field, no current flows.

   a. parallel   **c.** tangent

   b. perpendicular   **d.** indirectly

4. An electric current is generated in a wire in a constant magnetic field only when _____.

   a. the wire already has a small current   **c.** the wire is moved parallel to the field

   b. the wire moves across magnetic field lines   **d.** the wire is stationary in the field

5. *EMF* is measured in _____.

   a. amperes   **c.** ohms

   b. newtons   **d.** volts

6. Electromotive force is not a force; it is a _____.

   a. charge   **c.** potential difference

   b. current   **d.** resistance

7. Michael Faraday found that _____ could be produced by moving a wire through a magnetic field.

   a. a current

   b. an increase in resistance

   c. a net charge

   d. a magnetic force

8. The *EMF* produced in a wire moving in a magnetic field depends on _____.

   a. only the current in the wire

   b. only the magnetic field strength

   c. only the magnetic field strength, the length of the wire in the field, and the direction the wire moves

   d. the magnetic field strength, the length of the wire in the field, and the velocity of the wire

9. Which of the following statements are true for an alternating current electric generator?

   a. The average power is half of the maximum power.

   b. The effective current is about 71 percent of the maximum current.

   c. The effective voltage is about 71 percent of the maximum voltage.

   d. all of the above

Answer the following questions. Use complete sentences.

10. Write a definition for *EMF*.

    _____

    _____

11. What is one way to increase the induced *EMF* produced by a generator?

    _____

    _____

12. Describe how an electric generator works.

    _____

    _____

13. Explain how a sound wave is converted to an electric signal in a microphone.

    _____

    _____

14. Explain how an *EMF* is produced in a microphone.

    _____

    _____

    _____

25 ⌐ Study Guide

Section 25.2   Changing Magnetic Fields Induce *EMF*

In your textbook, read about Lenz's law on pages 679–681.

*For each statement below, write **true** or rewrite the italicized part to make the statement true.*

1. _____ The opposing force on an armature means that mechanical energy must be supplied to the generator to produce electric energy; this fact is consistent with *the law of conservation of energy*.

2. _____ If a generator produces a larger current, then the armature will be *easier* to turn.

3. _____ The direction of an induced current is such that the magnetic field resulting from the induced current opposes *the field* that caused the induced current.

4. _____ When a current is produced in a wire by electromagnetic induction, the direction of the current is such that the magnetic field produces a force on the wire that *assists* the original motion of the wire.

In your textbook, read about self-inductance on pages 681–682.

Write the term that correctly completes the statement. Use each term once.

work	energy	larger
constant	*EMF*	magnetic field lines
current	electric field	self-inductance
decreases	increases	zero

(**5**) _____ through a coil of wire generates a magnetic field. If the current

increases, the magnetic field (**6**) _____. This can be pictured as creation of new

(**7**) _____. As they expand, they cut through the coil of wires, generating a(n)

(**8**) _____ to oppose the current increase. This generating

process is called (**9**) _____. The faster the current changes, the

(**10**) _____ the opposing *EMF*, and the slower the current change. If the current

reaches a steady value, the magnetic field is (**11**) _____, and the *EMF* is

(**12**) _____. When the current (**13**) _____, the *EMF*

generated helps prevent the reduction in magnetic field and current. Because of self-inductance,

(**14**) _____ has to be done to increase the current in the coil.

(**15**) _____ is stored in the magnetic field, much like a charged capacitor that

stores energy in a(n) (**16**) _____.

In your textbook, read about transformers on pages 682–685.

Circle the letter of the choice that best completes the statement.

17. The two coils in a transformer must _____.

   a. be electrically insulated from each other

   b. be wound around different iron cores

   c. have the same number of windings

   d. have the same resistance

18. Transformers can change _____ with relatively little loss of energy.

   a. magnetic fields

   b. power

   c. resistances

   d. voltages

19. An insulated coil in which varying *EMF* is induced is _____.

   a. a primary coil

   b. a secondary coil

   c. found only in step-down transformers

   d. found only in step-up transformers

20. In an ideal transformer, the electric power delivered to the secondary circuit is _____ the power supplied to the primary circuit.

   a. double

   b. equal to

   c. greater than

   d. less than

21. In a step-up transformer, the number of coils of wire in the primary coil is _____ the number of coils in the secondary coil.

   a. double

   b. equal to

   c. greater than

   d. less than

22. In the secondary coil, the varying magnetic field induces a _____.

   a. charge

   b. resistance

   c. steady *EMF*

   d. varying *EMF*

23. When the primary coil is connected to a source of AC voltage, the changing current creates a _____.

   a. potential difference

   b. resistance

   c. steady magnetic field

   d. varying magnetic field

24. _____ in home appliances, adjust voltages to usable levels.

   a. Coils

   b. Magnets

   c. Currents

   d. Transformers

Complete the charts below by placing a greater-than sign (>), less-than sign (<), or equals sign (=) in each blank.

Step-Up Transformer	
Voltage	**24.** V_p _____ V_s
Current	**25.** I_p _____ I_s
Number of Turns	**26.** N_p _____ N_s
Power	**27.** P_p _____ P_s

Step-Down Transformer	
Voltage	**28.** V_p _____ V_s
Current	**29.** I_p _____ I_s
Number of Turns	**30.** N_p _____ N_s
Power	**31.** P_p _____ P_s

Answer the following questions. Show your calculations.

32. A transformer has a primary coil consisting of 150 turns and a secondary coil consisting of 4000 turns. The effective voltage supplied to the primary coil is 60.0 V.

  a. What is the induced *EMF* in the secondary coil?

  b. The secondary coil is part of a complete circuit with a resistance of 250 Ω. What is the current in the secondary circuit?

  c. What is the current in the primary circuit?

  d. Is this a step-up transformer or a step-down transformer?

CHAPTER
25 — Section 25-1 Quiz

1. What factors does the amount of current produced in a magnetic field depend on?

   _____

   _____

2. What is electromagnetic induction?

   _____

   _____

3. A straight wire that is 0.42 m long has a constant speed of 12.0 m/s perpendicular to a magnetic field that has a strength of 5.0×10^{-2} T.

   a. What is the induced *EMF* in the wire?

   b. If the wire is part of a circuit that has a resistance of 2.25 Ω, what is the current through the wire?

4. A generator can develop a maximum voltage of 1.20×10^2 V.

   a. What is the effective voltage of the generator?

   b. If a 1200-W space heater is powered by this generator and the generator has an I_{max} of 1.10 A, what is the effective current through the heater?

CHAPTER
25 — Section 25-2 Quiz

1. Define back-*EMF*.

   _____

   _____

2. Describe self-inductance.

   _____

   _____

3. What is the difference between a step-up transformer and a step-down transformer?

   _____

   _____

4. A step-up transformer has 400 turns on its primary coil and 1780 turns on its secondary coil, and has a voltage of 350.0 V across the primary circuit.

   a. What is the voltage in the secondary circuit?

   b. What is the ratio of the voltage in the primary coil to the voltage in the secondary coil?

   c. If there is a current in the primary circuit of 15.0 A, then what is the current in the secondary circuit?

CHAPTER
25 ___ Reinforcement

Transformers

Transformers are devices used to increase or decrease AC voltages with very little loss of energy. Step-up transformers allow a device such as a television tube, which may need 25,000 V, to get the voltage it needs from a wall outlet that usually supplies only 120 V. Likewise, a step-down transformer can allow a small device, such as a battery charger, to be supplied from the same outlet with as little as 1.5 V.

Imagine that you had to construct a transformer capable of running a television set that was going to be plugged into a conventional 120 V outlet that was on a 15 A line. On the primary coil of your transformer are 200 turns.

1. How many turns will you need on your secondary coil if the television needs 25,000 V to function?

2. What is the induced current in the secondary circuit?

3. From the numbers supplied, what is the resistance in the primary circuit?

4. What is the resistance in the secondary circuit?

5. What is the ratio of turns on the primary coil to turns on the secondary coil?

6. What is the ratio of volts across the primary circuit to volts across the secondary circuit?

7. What is the ratio of current in the primary circuit to current in the secondary circuit?

8. What is the ratio of resistance in the primary circuit to resistance in the secondary circuit?
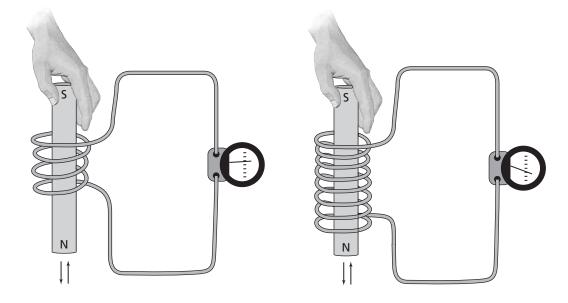
CHAPTER
25   Enrichment

Induced *EMF*

Induced *EMF* is a potential difference that has been created by electromagnetic induction and can be read as voltage on a voltmeter. Electromagnetic induction is the generation of current through a circuit due to the relative motion between a wire and a magnetic field.

Using 1 m of conducting wire, a voltmeter (or digital multimeter), and a bar magnet, construct the circuits seen in the image below, one at a time. The looped parts for the bar magnet consist of two, four, and eight loops, respectively.

25   **Enrichment**
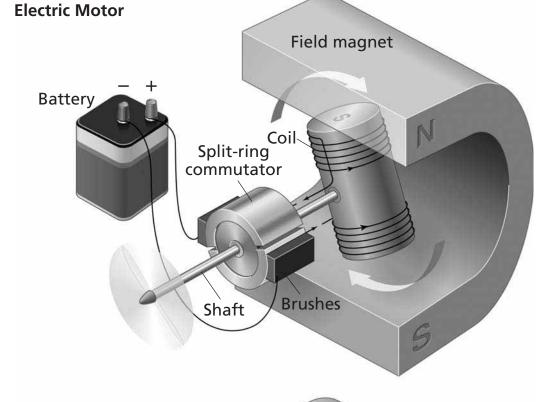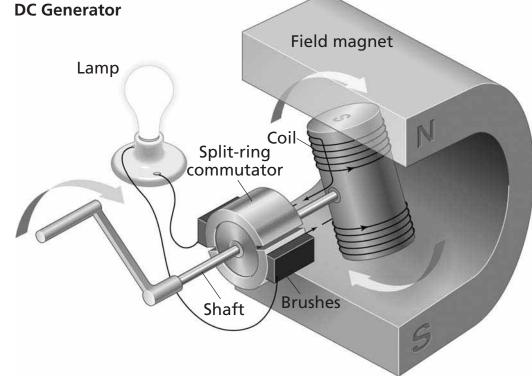
1. Move the bar magnet first through the two loops, then through the four loops, and finally through the eight loops. What differences in voltage do you see?

   _____

   _____

2. Move the bar through the loops at varying speeds. How does changing the speed affect the voltage reading?

   _____

   _____

3. What happens to the voltage if you reverse the direction the bar magnet travels through the loops?

   _____

   _____

4. Have a partner hold the magnet stationary while you move the loops up and down around it. How do the voltage readings compare to the readings produced when the loops were stationary and the magnet was moved?

   _____

   _____

5. How does the speed the loops travel affect the voltage readings?

   _____

   _____

6. How does changing the direction of travel of the loops affect the voltage readings?

   _____

   _____

Electric Motor/DC Generator

Electric Motor

Field magnet

Battery

− +

Coil

Split-ring commutator

S

N

Shaft

Brushes

DC Generator

Field magnet

Lamp

Coil

Split-ring commutator

S

N

Shaft

Brushes
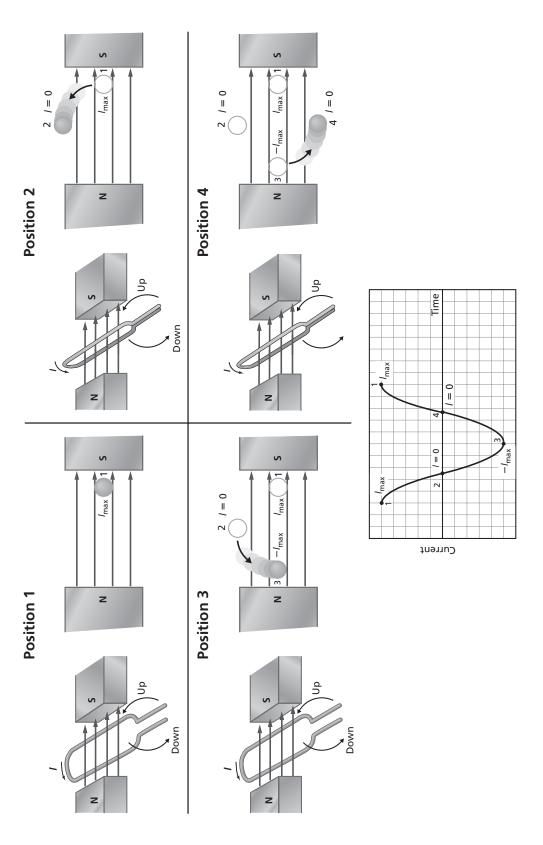
25 — Transparency 25-1 Worksheet

Electric Motor/DC Generator

1. In the diagram of the electric motor, what type of energy is running the motor and what is the source of the energy?

   _____

   _____

2. Locate and identify the armature of the electric motor. What force is acting on it, and what is the source of this force?

   _____

   _____

   _____

   _____

3. When the armature of the electric motor has rotated half a turn, how will the magnetic field of the armature be different?

   _____

   _____

4. In the diagram of the generator, note that there is no battery. What is the source of the energy for the generator system?

   _____

   _____

5. If there is no battery, how is electric current generated to light the bulb?

   _____

   _____

   _____

6. How would the generator system change if there were more coils in the armature?

   _____

AC Generator

Position 1

Position 2

Position 3

Position 4
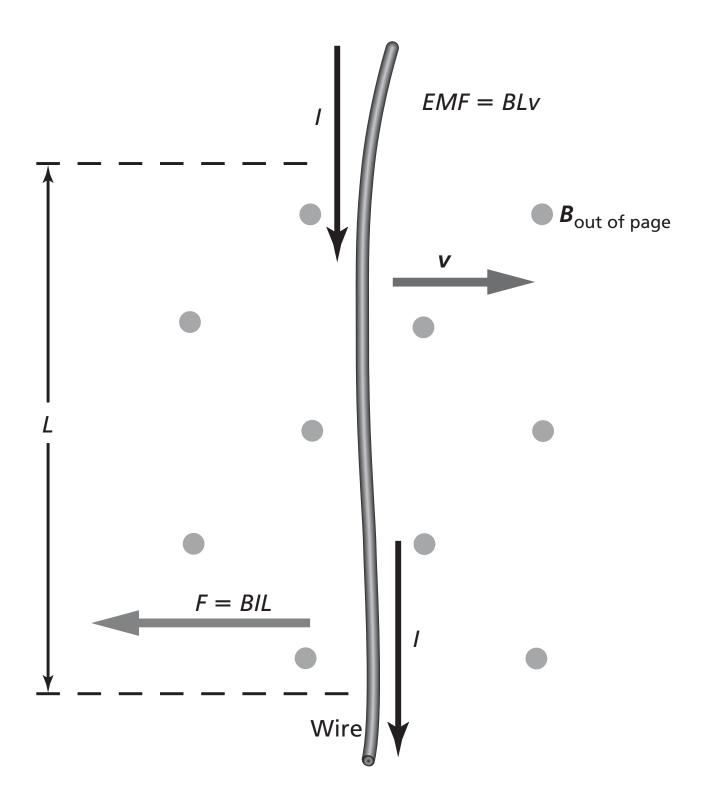
25 — Transparency 25-2 Worksheet

AC Generator

1. As the wire moves through position 1, how is it moving with respect to the magnetic field?

   _____

2. How much current is carried through the wire as it moves through position 1?

   _____

   _____

3. As the wire reaches position 2, how is it moving with respect to the magnetic field?

   _____

4. How is the change in the orientation of the wire in the magnetic field related to the amount of current induced in the wire?

   _____

   _____

   _____

   _____

   _____

   _____

   _____

5. How much current is carried through the wire as it moves through position 3?

   _____

Lenz's Law

I

$EMF = BLv$

$\mathbf{B}_{\text{out of page}}$

v

L

$F = BIL$

I

Wire
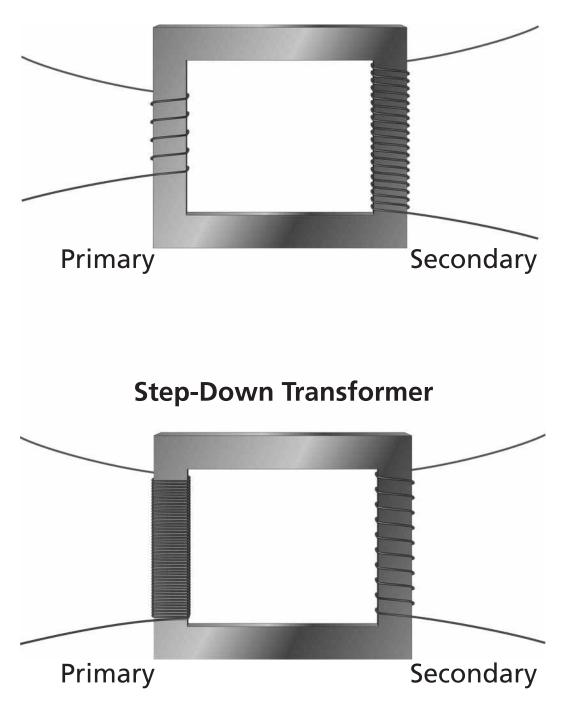
25 ⎯ Transparency 25-3 Worksheet

Lenz's Law

1. What is the direction of the current induced in the wire as a result of moving through the magnetic field? What rule is used to determine this direction?

_____

2. How does the direction of the force exerted by the magnetic field on the wire relate to the original motion of the wire?

_____

_____

3. What is Lenz's law?

_____

_____

_____

4. If the generator produces a small current, will the armature be easy or hard to turn? Why?

_____

_____

5. Why does placing a mechanical load on a motor cause more current to be carried through the motor?

_____

_____

_____

Transparency 25-4

Step-Up and Step-Down Transformers

Step-Up Transformer

Primary   Secondary

Step-Down Transformer

Primary   Secondary

25 ⎯ Transparency 25-4 Worksheet

Step-Up and Step-Down Transformers

1. In the step-up transformer, the primary coil has two turns, and the secondary coil has four turns. By what factor is the voltage in the primary circuit stepped up by the transformer?

   _____

   _____

   _____

   _____

2. If the voltage across the primary circuit of the step-up transformer were 120 V, what would be the voltage across the secondary circuit?

   _____

   _____

   _____

   _____

3. If the voltage across the primary circuit of the step-down transformer were 350 V, what would be the voltage across the secondary circuit?

   _____

   _____

   _____

   _____

4. If the current in the primary circuit of the step-down transformer were 40 A, what would be the current in the secondary circuit?

   _____

   _____

   _____

   _____

5. If the voltage in a transformer is stepped up, the current has been stepped down. Ohm's law indicates that increased voltage typically produces increased current. Explain this seeming contradiction.

   _____

   _____

   _____

CHAPTER
25 — Chapter Assessment

Understanding Physics Concepts

For each definition below, write the correct term.

electromagnetic induction	average power	step-up transformer
fourth right-hand rule	eddy current	step-down transformer
electromotive force	transformer	
electric generator	primary coil	

1. ——————————— a transformer with higher voltage across the secondary circuit than across the primary circuit

2. ——————————— a transformer with a lower voltage across the secondary circuit than across the primary circuit

3. ——————————— half of the maximum power generated by a generator

4. ——————————— the statement that if you hold your hand so that your thumb points in the direction the wire is moving, and your fingers point in the direction of the magnetic field, then your palm will point in the direction of the conventional (positive) current

5. ——————————— the generation of current through a circuit due to the relative motion between a wire and a magnetic field

6. ——————————— the potential difference that is produced by electromagnetic induction

7. ——————————— an insulated transformer coil that creates a varying magnetic field when it is connected to an alternating-current voltage source

8. ——————————— a device that converts mechanical energy to electrical energy

9. ——————————— a device used to increase or decrease AC voltage with very little loss of energy

10. ——————————— a current that produces a magnetic field that opposes the motion that causes the current

For each statement below, write true *or rewrite the italicized part to make the statement true.*

11. _____ When a wire is moved *parallel* to a magnetic field, a current is created.

12. _____ An electric generator converts *thermal* energy to electrical energy.

13. _____ *Back-EMF* is in the direction that opposes the current in a current-carrying wire.

14. _____ An *eddy current* is generated when a piece of metal moves through a magnetic field.

15. _____ Transformers can be used to *increase* AC voltages.

16. _____ The secondary coil of a *step-down* transformer has a higher voltage across it than the primary coil.

17. _____ In a step-down transformer, the current is *less* in the secondary circuit than in the primary circuit.

18. _____ In the long-distance transmission of electric energy, there are step-up transformers that develop voltages as high as *480,000* V.

Circle the letter of the choice that best completes the statement.

19. The induction of *EMF* in a wire carrying a changing current is an example of _____.

   a. self-inductance   **c.** an eddy current

   b. mutual inductance   **d.** a step-up transformer

20. Another term for RMS (root mean square) voltage is _____.

   a. induced voltage   **c.** effective voltage

   b. induced *EMF*   **d.** effective *EMF*

21. The current is greatest in a closed loop of conductor when the loop's motion is _____ the magnetic field.

   a. slow and perpendicular to   **c.** fast and perpendicular to

   b. slow and parallel to   **d.** fast and parallel to

22. The heavy current required when a motor starts can cause _____ in the wires that carry current to the motor.

   a. a voltage drop   **c.** an eddy current

   b. a voltage surge   **d.** mutual inductance

23. The voltages in alternating-current circuits may be increased or decreased by _____.

   a. induced *EMF*   **c.** transformers

   b. secondary coils   **d.** primary coils

Thinking Critically

Answer the following questions. Show your calculations.

1. A 25.5-m wire moves perpendicular to a magnetic field of 4.42×10^{-4} T at a speed of 14.4 m/s. What *EMF* is induced in the wire?

2. An AC generator develops a maximum *EMF* of 5.00×10^2 V. What is the effective *EMF* delivered to an external circuit?

3. A step-up transformer has 350 turns on the primary coil and 1500 turns on the secondary coil. The primary coil has a voltage of 110 V across it.

   a. What is the voltage across the secondary circuit?

   b. The current in the secondary circuit is 15.0 A. What is the current in the primary circuit?

   c. What is the power input and output of the transformer?

4. The primary coil of a transformer has 725 turns and is connected to a 120.0-V source. How many turns would be needed in the secondary coil to supply 555 V?

Answer the following questions. Use complete sentences.

5. In an alternating-current generator, a current is induced in the armature according to Lenz's law. Explain why the induced current will not stop the rotation of the armature if the force turning the armature does not change.

_____

_____

_____

_____

_____

6. Explain why the law of conservation of energy is not violated in a step-up transformer when the primary voltage of 60 V induces a secondary voltage of 240 V.

_____

_____

_____

_____

7. In a nonideal transformer, the efficiency is less than 100 percent because some energy is converted to thermal energy. Explain how thermal energy might be produced in a transformer, which has no moving parts.

_____

_____

_____

_____

8. When an electric motor is turned off by removing its plug from a wall outlet, what causes a spark at the outlet? Why does the spark last only a moment?

_____

_____

_____

_____

Applying Physics Knowledge

Answer the following questions. Use complete sentences.

1. A loop of wire is connected to a galvanometer. If a bar magnet is dropped through the loop, what happens to the galvanometer?

_____

_____

_____

2. A bar magnet and a loop of wire are moving parallel to each other at the same velocity. What is the voltage induced in the loop? Explain.

_____

_____

_____

3. What happens to the induced *EMF* when the magnetic field strength is doubled?

_____

_____

4. Explain the primary difference between an electric motor and an electric generator.

_____

_____

_____

_____

5. Why do the lights in a room dim momentarily when a large appliance is turned on?

_____

_____

_____

_____

6. What happens to the voltage across the secondary coil of a step-up transformer if the number of turns in the primary coil is doubled while the voltage across the primary coil is left the same?

_____

_____

_____

Answer the following questions. Show your calculations.

7. The current carried through a wire is 1.34×10^{-2} A. The wire is connected across a circuit with 5.50 Ω of resistance. If 1.12 m of the wire is moving perpendicularly through a magnetic field of 0.250 T, then what is the velocity of the wire?

8. An AC generator requires 225 J of mechanical energy per second to produce 175 W of effective power.

a. What is the efficiency of the generator?

b. If the total resistance in the wire in the generator is 15.0 Ω, then what is the maximum current produced?

9. If the average power dissipated by an electric light is 150 W, what is the maximum power?

10. A 220-W transformer has an input voltage of 35 V and an output voltage of 12 V. What is the ratio of turns in the primary coil to turns in the secondary coil?

Answer Key

Chapter 21

Mini Lab

Analyze and Conclude

5. The opposite charges attract.

6. The field is strongest near the center of the foam, and gets stronger as the distance between the objects decreases.

7. The greater the angle of the thread, the greater the field strength. The ball is repelled, so the thread moves in the direction of the field.

Physics Lab

Sample Data
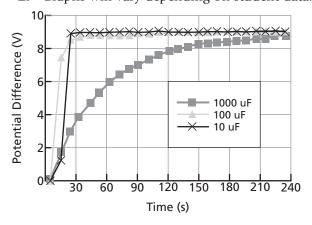
Time (s)	Voltage (V) on 1000 μF	Voltage (V) on 100 μF	Voltage (V) on 10 μF
0	0	0	0
10	1.7	7.5	1.3
20	2.9	8.6	8.9
30	3.8	8.7	9
40	4.7	8.8	9
50	5.3	8.8	9
60	5.9	8.8	9
70	6.4	8.8	9
80	6.7	8.8	9
90	7.0	8.9	9
100	7.3	8.9	9
110	7.6	9	9
120	7.8	9	9
130	7.9	9	9
140	8.1	9	9
150	8.2	9	9

Sample Data *continued*

Time (s)	Voltage (V) on 1000 μF	Voltage (V) on 100 μF	Voltage (V) on 10 μF
160	8.3	9	9
170	8.4	9	9
180	8.4	9	9
190	8.5	9	9
200	8.5	9	9
210	8.6	9	9
220	8.6	9	9
230	8.7	9	9
240	8.7	9	9

Analyze

1. Answers will vary. Many capacitors may not charge to 9 volts. They may reach an equilibrium at a lower voltage with the energy leaking off as quickly as it is flowing onto the capacitor, especially in the presence of high humidity.

2. Graphs will vary depending on student data.

Conclude and Apply

1. No, because it takes time to build up charges on the capacitor depending upon its capacitance. The increase is exponential. The voltage equals the charge/capacitance.

2. The larger capacitor requires more time to become fully charged.
Note: Many larger capacitors are called electrolytic capacitors and have as much as 100% variance in their stated value of capacitance, so it is possible that some of the capacitors students use may have different results for same stated capacitance.

Going Further

1.

Capacitor (μF)	Time Constant (s)
1000	47
100	4.7
10	0.47

2. Answers will vary because of variance in actual capacitance value. Sample data time constants match well.

Real-World Physics

The capacitor must charge to a set value before the flash is ready to work. The factors contributing to the time it takes to charge the flash include the size (capacitance) of the capacitor, and the available current.

Note that the flash tends to charge more quickly with fresh batteries than with old ones.

Chapter 21 Study Guide

Vocabulary Review

1. a
2. c
3. e
4. f
5. d
6. g
7. b

Section 21.1
Creating and Measuring Electric Fields

1. Field lines do not actually exist, but electric fields do. Field lines provide a model of an electric field. Electric fields provide a method of calculating the force on a charged body.

2. A Van de Graaff generator transfers large amounts of charge from one part of the machine to the top metal terminal. A person touching the terminal is charged electrically. The charges on the person's hair repel one another, causing the hairs to follow the field lines.

3. The vector sum of the two charges can be used to find the electric field.

4. The force exerted on a test charge in an electric field is proportional to the size of the test charge.

5. The length of the arrow indicates the magnitude of the field. The direction of the arrow indicates the field direction.

6. An electric charge produces an electric field.

7. An electric field can be observed only when it produces forces on other charges.

8. The test charge exerts a force on q. It is important that the force exerted by the test charge not move q to a new location, and thus change the force on q' and the electric field being measured.

9. $E = \dfrac{F}{q'}$

$= \dfrac{1.2 \text{ N}}{1.4 \times 10^{-7} \text{ C}}$

$= 8.6 \times 10^6 \text{ N/C}$

10. $q' = \dfrac{F}{E}$

$= \dfrac{1.2 \times 10^{-3} \text{ N}}{4.4 \times 10^6 \text{ N/C}}$

$= 2.7 \times 10^{-10} \text{ C}$

11. $F = Eq$

$= (9.9 \times 10^7 \text{ N/C})(1.6 \times 10^{-19} \text{ C})$

$= 1.6 \times 10^{-11} \text{ N}$

Section 21.2
Applications of Electric Fields

1. c
2. c
3. b
4. d
5. d
6. true
7. potential

8. true

9. higher

10. One is charged negatively, and one is charged positively.

11. $\Delta V = Ed$
$= (350 \text{ N/C})(0.12 \text{ m})$
$= 42 \text{ V}$

12. $W = q\Delta V$
$= (5.1\times10^{-6} \text{ C})(42 \text{ V})$
$= 2.1\times10^{-4} \text{ J}$

13. $E = \dfrac{\Delta V}{d}$
$= \dfrac{120 \text{ V}}{0.26 \text{ m}}$
$= 4.6\times10^2 \text{ N/C}$

14. $q = \dfrac{W}{\Delta V}$
$= \dfrac{1.4\times10^{-3} \text{ J}}{120 \text{ V}}$
$= 1.2\times10^{-5} \text{ C}$

15. $C = \dfrac{q}{\Delta V}$
$= \dfrac{2.2\times10^{-6} \text{ C}}{240 \text{ V}}$
$= 9.2\times10^{-9} \text{ F}$

16. $\Delta V = \dfrac{q}{C}$
$= \dfrac{9.6\times10^{-5} \text{ C}}{5.8\times10^{-7} \text{ C/V}}$
$= 1.7\times10^2 \text{ V}$

17. $\Delta V = Ed$
$d = \dfrac{\Delta V}{E}$
$= \dfrac{12.0 \text{ V}}{250 \text{ N/C}}$
$= 4.8\times10^{-2} \text{ m}$

18. $\Delta V = \dfrac{W}{q}$
$= \dfrac{1.22 \text{ J}}{3.22 \ \mu\text{C}}$
$= 3.79\times10^{-1} \text{ V}$

19. $C = \dfrac{q}{\Delta V}$
$q = C\Delta V$
$= (45\times10^{-6} \text{ F})(85 \text{ V})$
$= 3.8\times10^{-2} \text{ C}$

20. $C = \dfrac{q}{\Delta V}$
$\Delta V = \dfrac{q}{C}$
$= \dfrac{1.33\times10^{-6} \text{ C}}{12.2\times10^{-12} \text{ F}}$
$= 1.09\times10^7 \text{ V}$

Section 21-1 Quiz

1. q' must be very small so that it is not able to move q in the testing process and change the strength of the field from q.

2. F indicates the force exerted on a charge by an electric field, E is the electric field strength, and q is the magnitude of the charge in the field.

3. Conventionally, positive charges are shown with arrows pointing radially outward like the spokes of a wheel, and negative charges are shown with the arrows pointing inward in the same arrangement. In both cases the density of the lines indicates the strength of the field.

4. The field is to the left.
$E = \dfrac{F}{q}$
$= \dfrac{0.025 \text{ N}}{1.5\times10^{-8} \text{ C}}$
$= 1.7\times10^6 \text{ N/C}$

5. $F = Eq$
$= (5.1\times10^5 \text{ N/C})(3.4\times10^{-6} \text{ C})$
$= 1.7 \text{ N}$

Section 21-2 Quiz

1. A volt is equal to a joule/coulomb (V = J/C).

2. Capacitors use two conductors separated by an insulator to store charge. The two conductors have equal but opposite charges and the insulator prevents the charge from moving from one conductor to the other, thus allowing the capacitor to store the charge on its conductors.

3. $E = \dfrac{\Delta V}{d}$

$\quad = \dfrac{120 \text{ V}}{0.140 \text{ m}}$

$\quad = 8.6 \times 10^2 \text{ N/C}$

4. $W = q\Delta V$

$\quad = (2.2 \times 10^{-4}\text{C})(120 \text{ V})$

$\quad = 0.026 \text{ J}$

5. $C = \dfrac{q}{\Delta V}$

$\quad = \dfrac{4.5 \times 10^{-5} \text{ C}}{35 \text{ V}}$

$\quad = 1.3 \times 10^{-6} \text{ F}$

Chapter 21 Reinforcement
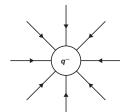
1. $\Delta V = \dfrac{W}{q}$ rearranges to form $W = q\Delta V$, and

$C = \dfrac{q}{\Delta V}$ rearranges to form $q = C\Delta V$, so

when $C\Delta V$ is substituted into $W = q\Delta V$ for q, the solution is $W = C\Delta V^2$.

2. In Question 1, the solution was $W = C\Delta V^2$, and the expression $C\Delta V^2$ can be plugged

into the formula $P = \dfrac{W}{t}$ for W. This yields

the result $P = \dfrac{C\Delta V^2}{t}$.

3. $\Delta V = \dfrac{W}{q}$ rearranges to form $W = q\Delta V$, and

$E = \dfrac{F}{q}$ rearranges to form $q = \dfrac{F}{E}$, so

plugging $\dfrac{F}{E}$ for q in $W = q\Delta V$ produces the

formula $W = \dfrac{F\Delta V}{E}$.

Chapter 21 Enrichment
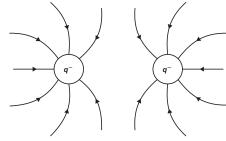
Electric Field Lines

1.

2.

3.

4.

5.

6.

Answer Key

7.

8.
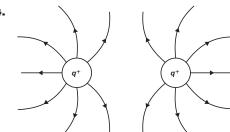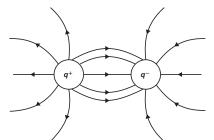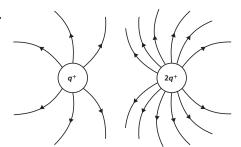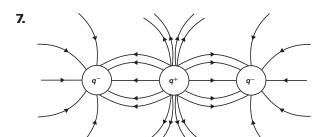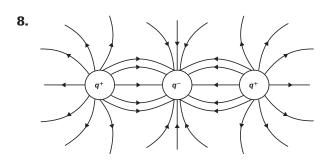
9. There are half as many lines on the smaller charge as on the stronger charge.

10. The number of field lines in Question 3 is equal to the number of field lines in Question 4, but they point in the opposite direction.

11. The number of field lines in Question 7 is equal to the number of field lines in Question 8, but they point in the opposite direction.

12. Field lines are not real. They are models that help you visualize the magnitude and direction of an electric field.

13. Electric fields are real and are represented by electric field lines.

Transparency 21-1 Worksheet

Electric Field Lines

1. The force that is causing the filings to align in a pattern is the electric field that surrounds the charged objects.

2. One conductor has a positive charge, and the other has a negative charge. A large portion of the field lines start at one conductor and end at the other, which is common for oppositely charged conductors that are close together.

3. The two conductors are both negatively or both positively charged. The field lines do not cross from one conductor to the other. In fact, they show signs of being repelled by one another, which is common for two conductors that have like charges.

4. A large majority of the field lines coming from the positive conductor terminate in the negative conductor.

5. Where the field lines terminate is not known, but the field lines from one conductor do not terminate at the other conductor.

6. The concentric circles are areas of equipotential. The potential difference from point to point around the circle is zero.

7. The density of the field lines indicates the relative strength of the field around the conductor. Few lines indicate a weak field, while many lines indicate a strong field.

8. Field lines never cross one another, although lines from one conductor may terminate at another conductor.

Transparency 21-2 Worksheet

Millikan's Apparatus

1. He used it to measure the charge of an electron.

2. When the potential difference is adjusted so that the upward force of the electric field is equal to the downward force of gravity, the drops are suspended.

3. It is used to spray fine oil drops into the air.

4. The battery is used to place a potential difference across the two plates.

5. They become charged by friction with the atomizer as they are sprayed.

6. An object can have only a charge with a magnitude that is an integral multiple of the charge of an electron.

7. They are attracted to the positive plate.

8. A potential difference is placed across the two oppositely charged plates, creating an electric field between them that exerts a force on the charged drops.

9. He used the terminal velocity of the oil drop and the magnitude of the electric field.

10. Each electron carries the same charge: -1.6×10^{-19} C.

Transparency 21-3 Worksheet

Sharing Charges

1. The charged sphere has a high potential, and the neutral sphere has zero potential.

2. They are equal.

3. Negative charges are transferred from the charged sphere to the neutral sphere until the two spheres are at the same potential.

4. The sphere on the far left side has the greatest potential because it has the most excess negative charges for the same amount of surface area.

5. They move from the smaller sphere to the larger sphere.

6. Charges flow until all parts of a conduction body are at the same potential. When the spheres first touch and become a conducting body, the right side of that body has a higher potential than the left side, so the charges move toward the left until the potential is the same throughout the body.

7. Both show two spheres touching. In Figure A, both the charge and potential of the spheres are equal. In Figure B, the spheres have equal potential, but the larger sphere has a greater charge.

8. In order to spread as far apart as possible, the charges in a hollow sphere move to the outer surface.

9. It would be strongest at the sharp point.

Transparency 21-4 Worksheet

Capacitors

1. A capacitor consists of two oppositely charged plates separated by a distance or an insulator. The capacitor is designed to store charge in electric circuits.

2. The magnitude of the charge on the negative plate is equal to the magnitude of the charge on the positive plate even though they have opposite charges.

3. The field between the plates of a capacitor flows from the positive plate toward the negative plate.

4. The field on the side of the negative plate near the conductor flows toward the negative plate.

5. The field on the side of the positive plate near the conductor flows away from the positive plate.

6. *C* stands for capacitance, which is measured in farads or coulombs per volt. *q* stands for quantity of charge, which is measured in coulombs. *V* is voltage, or potential difference, measured in volts.

7. Possible answers are camera flashes, computers, and televisions.

8. $C = \dfrac{q}{\Delta V}$

   $= \dfrac{5.8 \times 10^{-6} \text{ C}}{60 \text{ V}}$

   $= 1 \times 10^{-7}$ F

Chapter 21 Assessment

Understanding Physics Concepts

1. d
2. c
3. f
4. g
5. a
6. b
7. e
8. c
9. a
10. a
11. a
12. d
13. true
14. true
15. volt
16. true
17. electron
18. outer
19. true
20. equipotential

21. unlike

22. forces

23. positive, toward

24. cross, stronger

25. volts

26. grounding

27. conductors

28. capacitors

Thinking Critically

1. $W = q\Delta V$
$= (1.20 \text{ C})(48.0 \text{ V})$
$= 57.6 \text{ J}$

2. $\Delta V = Ed$
$= (1.9 \times 10^4 \text{ N/C})(0.046 \text{ m})$
$= 8.7 \times 10^2 \text{ V}$

3. $\Delta V = \dfrac{W}{q}$
$q = \dfrac{W}{\Delta V}$
$= \dfrac{1200 \text{ J}}{6.0 \text{ V}}$
$= 2.0 \times 10^2 \text{ C}$

4. $E = \dfrac{\Delta V}{d}$
$= \dfrac{26 \text{ V}}{0.022 \text{ m}}$
$= 1.2 \times 10^3 \text{ N/C}$

5. $q = \dfrac{F}{E}$
$= \dfrac{2.21 \times 10^{-5} \text{ N}}{3.30 \times 10^{-6} \text{ N/C}}$
$= 6.70 \text{ C}$

6. $E = \dfrac{F}{q}$
$= \dfrac{0.55 \text{ N}}{8.8 \times 10^{-6} \text{ C}}$
$= 6.3 \times 10^4 \text{ N/C}$

7. $\Delta V = \dfrac{W}{q}$
$= \dfrac{3.3 \text{ J}}{1.2 \text{ C}}$
$= 2.8 \text{ V}$

8. $d = \dfrac{\Delta V}{E}$
$= \dfrac{12.2 \text{ V}}{555 \text{ N/C}}$
$= 2.20 \times 10^{-2} \text{ m}$

9. $F = Eq$
$= (4.54 \times 10^{-4} \text{ N/C})(19.9 \text{ C})$
$= 9.03 \times 10^3 \text{ N}$

10. $E = \dfrac{F}{q}$
$= \dfrac{7.7 \times 10^{-8} \text{ N}}{3.4 \times 10^{-3} \text{ C}}$
$= 2.3 \times 10^{-5} \text{ N/C}$

Applying Physics Knowledge

1. Both an electric field and a gravitational field act between bodies that are not in contact with each other. In a gravitational field, one mass exerts a force on another mass. In an electric field, one charge exerts a force on another charge. An electric field is the force per unit charge. A gravitational field is the force per unit mass. Electric fields can both attract and repel and gravitational fields only attract.

2. Since like charges repel each other, more work is done bringing them together than bringing together unlike charges. Thus, work has to be put into the system and the potential energy of the system increases.

3. Yes. The car is a closed metal conductor that is hollow. Charges move to the external surface, shielding the interior from the electric field. As long as the people do not touch an external surface, they will be safe.

4. The field is away from the negative plate and toward the positive plate.

5. The net charge on a capacitor is zero, since the two conductors have equal and opposite charges.

6. $W = q\Delta V$ and $q = C\Delta V$
$= C\Delta V^2$
$= (1.44 \times 10^{-5} \text{ F})(955 \text{ V})^2$
$= 13.1 \text{ J}$

7. $W = C\Delta V^2$ and $P = \dfrac{W}{t}$

$P = \dfrac{C\Delta V^2}{t}$

$= \dfrac{(2.2\times10^{-5}\text{ F})(980\text{ V})^2}{25\text{ s}}$

$= 0.85\text{ W}$

8. $W = q\Delta V$ and $q = \dfrac{F}{E}$

$= \dfrac{F\Delta V}{E}$

$= \dfrac{(2.8\times10^4\text{ N})(11\text{ V})}{3.9\times10^{-3}\text{ N/C}}$

$= 7.9\times10^7\text{ J}$

9. $\Delta V = Ed$ and $E = \dfrac{F}{q}$
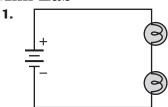
$= \dfrac{Fd}{q}$
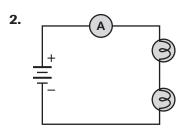
$= \dfrac{(4.7\times10^3\text{ N})(0.24\text{ m})}{2.6\times10^{-2}\text{ C}}$
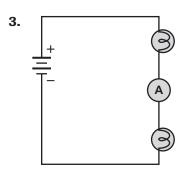
$= 4.3\times10^4\text{ V}$

Chapter 22

Mini Lab

1.

2.

3.

Analyze and Conclude

4. Students' predictions will vary.

5. Students should find that the current is the same at all points in the circuit.

Physics Lab

Sample Data

Data Table 1
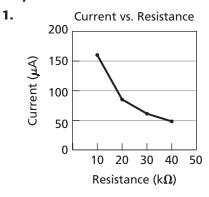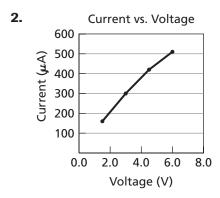
Voltage (V)	Resistance (kΩ)	Current (µA)
1.5	16	160
1.5	20	85
1.5	30	61
1.5	40	48

Data Table 2

Voltage (V)	Resistance (kΩ)	Current (µA)
1.5	10	160
3.0	10	300
4.5	10	420
6.0	10	510

Analyze

1.

Current vs. Resistance

2.

Current vs. Voltage

3. Because wires are not totally resistance free, some energy could be lost to the wires. Also, resistance tends to increase as wires or resistors heat up.

4. Because wires are not totally resistance free, some energy could be lost to the wires. Also, resistance tends to increase as wires or resistors heat up.

Conclude and Apply

1. There is an inverse relationship between resistance and current. As resistance increases, current decreases and vice versa.

2. This inverse relationship exists because resistance decreases the current.

3. There is a linear relationship between voltage and current. As voltage increases, current increases.

4. This relationship exists because voltage is the potential difference that pushes the charges through the circuit and creates current.

Going Further

1. The current would be around 160 mA. Doubling the voltage will compensate for the doubling of the resistance.

2. $V = IR$

3. The data should match rather well, but may become further off as current increases.

Real World Physics

1. Answers include electric ranges, hot water heaters, dryers, and refrigerators.

2. Since $P = IV$ and P stays the same, the current will go up if voltage drops. As a result, much more energy will be dissipated as heat.

Chapter 22 Study Guide

Current Electricity
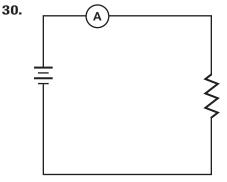
Vocabulary Review
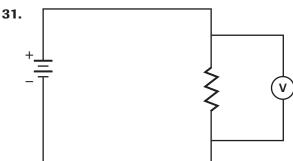
1. superconductor
2. resistance
3. electric current
4. series connection
5. kilowatt hour
6. parallel connection
7. ampere
8. electric circuit
9. battery
10. conventional current
11. resistor
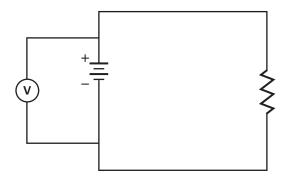
Section 22.1
Current and Circuits

1. positive
2. positive charge
3. true
4. motor
5. true
6. charge pump
7. reduces
8. energy
9. light
10.

11. The battery increases the potential energy of the electrons. The heater decreases the potential energy of the electrons.

12. Charges cannot be created or destroyed.

13. No. If the current leaving the heater were different from the current that enters, that would mean there was a loss/gain of electrons in the resistor. A change is not possible because charge is conserved.

14. d
15. a
16. b
17. d
18. power
19. $P = \dfrac{E}{t}$
20. charge
21. potential
22. $E = qV$
23. current
24. $I = \dfrac{q}{t}$
25. $P = IV$
26. d
27. b
28. a
29. a
30.

31.

Section 22.2
Using Electrical Energy

1. $P = \dfrac{V^2}{R}$

$= \dfrac{(9.0\ V)^2}{100\ \Omega}$

$= 0.8\ W$

2. $E = Pt$

$P = \dfrac{V^2}{R}$

$E = \left(\dfrac{V^2}{R}\right)t$

$ = \left(\dfrac{(110\ V)^2}{220\ \Omega}\right)\left(24\ h\right)\left(\dfrac{60\ min}{h}\right)\left(\dfrac{60\ s}{min}\right)$

$ = 4.8 \times 10^6\ J$

3. The flowing electrons bump into the atoms in the resistor, increasing their kinetic energy. The increase in the kinetic energy of the atoms results in an increase in the temperature of the resistor.

4. hair dryer, curling iron, clothes iron, toaster oven, toaster, hot plate, space heater, immersion heater

5. No, because it would damage the toaster. When too much current is drawn through an appliance—or, as in this case, when excess voltage is applied—then overheating results, and this damages the appliance.

Answer Key

6. d

7. a

8. f

9. e

10. c

11. b

12. c

13. a

14. a

15. b

16. b

17. c

Section 22-1 Quiz

1. $I = \dfrac{q}{t}$

$\quad = \dfrac{20 \text{ C}}{4 \text{ s}}$

$\quad = 5 \text{ A}$

2. $P = IV$

$\quad = (0.5 \text{ A})(6.0 \text{ V})$

$\quad = 3 \text{ W}$

3. length, cross-sectional area, temperature, and kind of metal

4. $I = \dfrac{V}{R}$

$\quad = \dfrac{90 \text{ V}}{30 \text{ }\Omega}$

$\quad = 3 \text{ A}$

5. $R = \dfrac{V}{I}$

$\quad = \dfrac{120 \text{ V}}{0.50 \text{ A}}$

$\quad = 2.4 \times 10^2 \text{ }\Omega$

6. Ammeters are used to measure the current in a circuit. Since ammeters are inserted in series, any resistance from the ammeter will decrease the current. A small resistance is used to minimize the decrease in current.

Section 22-2 Quiz

1. The current flowing through your body causes the pain. Voltage is just a measure of the difference in charge potential between two points.

2. When a current is flowing, electrons are moving in the wire. They collide with the atoms in the wire and increase the kinetic energy of the atoms.

3. $P = \dfrac{V^2}{R}$

$\quad = \dfrac{(120 \text{ V})^2}{100 \text{ }\Omega}$

$\quad = 100 \text{ W}$

4. $E = Pt$

$\quad = (100 \text{ W})(20 \text{ s})$

$\quad = 2000 \text{ J}$

5. $E = Pt$

$\quad = \left(\dfrac{365 \text{ days}}{\text{y}} \right)\left(\dfrac{24 \text{ h}}{\text{day}} \right)\left(\dfrac{60 \text{ min}}{\text{h}} \right)$
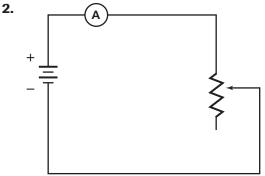
$\qquad \left(\dfrac{60 \text{ s}}{\text{min}} \right)\left(\dfrac{40 \text{ J}}{\text{s}} \right)\left(\dfrac{\text{kWh}}{3.6 \times 10^6 \text{ J}} \right)$

$\quad = 400 \text{ kWh}$

6. The consumers are usually many miles away, and it is important to reduce the loss of energy by heating up the transmission wires. The heat loss is diminished by reducing the current, which is, in turn, accomplished by increasing voltage. Once the energy has reached the consumer, the high voltage and low current are no longer needed and they are returned to their former states using a transformer.

Chapter 22 Reinforcement
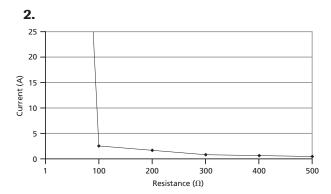
Procedure

2.
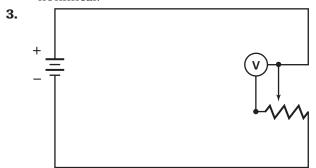
Results

1.

V	R	I
250 V	1.0 Ω	250 A
250 V	1.0×10^2 Ω	2.50 A
250 V	2.0×10^2 Ω	1.2 A
250 V	3.0×10^2 Ω	0.83 A
250 V	4.0×10^2 Ω	0.62 A
250 V	5.0×10^2 Ω	0.50 A

2.

Note: whereas the graph of the available data shows a linear decrease in current from 1 Ω to 100 Ω, in actuality the relationship is nonlinear.

3.

Chapter 22 Enrichment

1. $I = \dfrac{V}{R}$

$I_1 = \dfrac{36 \text{ V}}{18 \text{ Ω}} = 2.0 \text{ A}$

$I_2 = \dfrac{36 \text{ V}}{9 \text{ Ω}} = 4 \text{ A}$

$I_3 = \dfrac{36 \text{ V}}{6 \text{ Ω}} = 6 \text{ A}$

2. $I = \dfrac{V}{R} = \dfrac{36 \text{ V}}{3 \text{ Ω}} = 10 \text{ A}$

3.

$R = 6 \text{ Ω} + 9 \text{ Ω} + 18 \text{ Ω} = 33 \text{ Ω}$
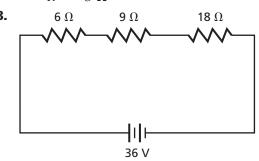
4. In a parallel circuit, there are more paths for the electrons to follow, so the effective or equivalent resistance is less than the resistance when the resistors are connected along a single path.

5. For series circuits, first recall that the net change in potential energy of charges going completely around a circuit must be zero. In other words, the increase in potential from the power source is equal to the decrease in potential due to the resistance in the circuit.

$V_{\text{battery}} = V_{R1} + V_{R2} + V_{R3}$

Since the voltage drop across each resistor is $V = RI$ and since the current through each resistor is the same in a series circuit

$V_{\text{battery}} = IR_1 + IR_2 + IR_3$
$V_{\text{battery}} = I(R_1 + R_2 + R_3)$

$I = \dfrac{V_{\text{battery}}}{R_1 + R_2 + R_3}$

$R_1 + R_2 + R_3 = \dfrac{V_{\text{battery}}}{I}$

For the entire circuit:

$I = \dfrac{V_{\text{battery}}}{R_{\text{eq}}}$

$R_{\text{eq}} = \dfrac{V_{\text{battery}}}{I}$

Using substitution, you now come up with the following equation for resistance in series circuits:

$R_{\text{eq}} = R_1 + R_2 + R_3$

For parallel circuits, recall that the voltage across each branch of a parallel circuit is the

same. For the parallel circuit in this Enrichment, the voltage across each of the resistors would be 36 V. Also recall that the current is split between each branch of the circuit but that the total current in the circuit is the sum of the currents in each branch of the circuit. Thus,

$$I = I_1 + I_2 + I_3$$

Since the voltage is the same for each resistor,

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{I}{V}$$

For the entire circuit:

$$I = \frac{V}{R_{eq}}$$

$$\frac{1}{R_{eq}} = \frac{I}{V}$$

Using substitution, you come up with the following formula for resistances in parallel:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Transparency Worksheet 22-1

Parts of an Electric Circuit

1. $P = \dfrac{V^2}{R}$

$$= \frac{(3\ V)^2}{30\ \Omega}$$

$$= 0.3\ W$$

2. $R = 30\ \Omega$

$V = 3\ V$

$$I = \frac{V}{R}$$

$$= \frac{3\ V}{30\ \Omega}$$

$$= 0.1\ A$$

3. Power varies inversely with resistance. Thus, as the resistance of the bulb increases, the amount of power the bulb uses decreases and vice versa.

4. $E = Pt$

$$= (0.3\ W)(3600\ s)$$

$$= 1000\ J$$

Transparency Worksheet 22-2

Circuit Symbols

1. Resistance is the property of an object that determines how much current will flow through that object. The resistance of an object, such as a wire, is determined by length, cross-sectional area, temperature, and the material the object is made of.

2. Voltage is a potential difference. In other words, voltage is potential energy. Current is the movement of charge due to a potential difference. Thus, voltage is nothing more than a difference in potential and does not necessarily create a current. Given the proper conditions, however, voltage causes charges to move and when they do, a current is created.

3. Resistance is defined as voltage divided by current. Since the voltage remains the same and the resistance is increasing, the current through the circuit must be decreasing.

4. They allow complex circuits to be graphically illustrated clearly and concisely.

Transparency Worksheet 22-3

Inside a Flashlight

1. According to the picture of the flashlight, the current will flow clockwise.

2. When the switch is in the off position, the bulb in the flashlight is only connected to one side of the batteries, and thus there is no potential difference across the bulb. When the switch is moved to the on position, the bulb is connected to both the positive and negative terminals of the batteries, and a potential difference is created across the bulb. The potential difference causes a current to flow and the light turns on.

3. Since voltage is equal to the product of resistance and current, an increase in voltage would result in an increase in current.

4. The amount of energy the flashlight uses per unit of time is power. Power is directly proportional to the square of voltage so an increase of 2 V in potential would result in an increase of 4 W in power.

Transparency Worksheet 22-4

Electric Power Transmission

1. The amount of energy lost each second over transmission wires (power) is proportional to the square of the current in those wires ($P = I^2R$).

2. It is important to minimize current because increases in current result in increases in thermal energy lost over transmission lines.

3. Since power is equal to the product of current and voltage ($P = IV$), current can be reduced if voltage is increased. In this way no power is lost. The loss of thermal energy can be minimized by reducing the resistance, R.

4. Few household devices require extremely high voltages such as those used in transmission of electricity, and extremely high voltages are potentially quite dangerous.

Chapter 22 Chapter Assessment

Current Electricity
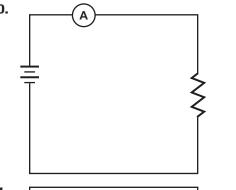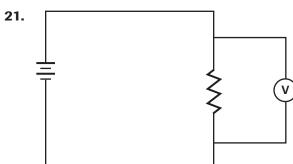
Understanding Physics Concepts
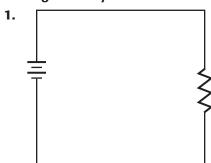
1. c
2. d
3. e
4. b
5. f
6. a
7. d
8. d
9. d
10. d
11. d
12. b
13. b
14. d
15. a
16. b

17. c
18. c
19. d
20.

21.

Thinking Critically

1.
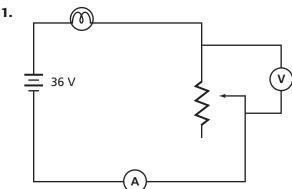
2. The man increases the gravitational potential energy of the bowling balls, and the battery increases the electrical potential energy of the electrons in the circuit.

3. It is converted into heat or converted into the kinetic energy the grease obtains from the ball.

4. Electrons heat up a resistor as they move through the resistor just as the bowling balls heat up the grease as they pass through the grease. Also, like the number of electrons, the number of bowling balls does not
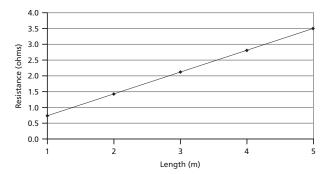
change. Like the potential energy of the electrons, the potential energy of the bowling ball is converted into heat.

5. Since a connecting wire has very little resistance, there is a very small loss of electrical potential energy when electrons move along such a wire. If the tracks are horizontal, there is no loss of gravitational potential energy.

6. With a greater length of wire, the material contains more atoms and electrons along the path to collide and impede the progress of an electrical current.

7. In a thicker wire, there is more material in the cross-section and thus more pathways for electrons to move and an electrical current to flow.

8. At a higher temperature, the kinetic energy of the atoms in the wire is greater. Thus, there are more collisions with the electrons.

9. Yes; the number of collisions between the electrons and the atoms will depend on the atomic structure of the material. Some structures allow for greater movement of electrons while others are irregular and greatly impede the flow of free electrons.

Applying Physics Knowledge

1.

2. $I = \dfrac{V}{R}$; The current values will be 36 A, 0.4 A, 0.2 A, and 0.1 A, respectively.

3. $R = \dfrac{V}{I}$; For 1.0 A, 12 A, and 18 A, and 36 A the resistance of the potentiometer is 36 Ω, 3.0 Ω, 2.0 Ω, and 1.0 Ω accordingly.

4.

Length (m)	Current (A)	Voltage (V)	Resistance (Ω)
1	12.7	9	0.7
2	6.4	9	1.4
3	4.3	9	2.1
4	3.2	9	2.8
5	2.6	9	3.5

$$\text{Slope} = \frac{R}{L} = \frac{0.7\ \Omega}{\text{m}}$$
$$R = (0.7\ \Omega\,/\text{m})L$$

5. As the thickness of a wire increases, so does its cross-sectional area. With a larger cross-sectional area, there are more pathways for an electric current to flow through the material.

6. The number of electrons in a segment of wire is proportional to the length of the segment times the area of the wire. In comparing two wires of the same length the number of electrons is directly proportional to the area or the square of the thickness.

7. Since metal is a solid, the atoms are packed closely together so it would be impossible for the electrons to travel quickly through a wire. Electricity travels fast in the sense that when you connect a circuit, all of the electrons in the circuit start moving almost at once.

Chapter 23

Mini Lab

Steps 1. and 3. Student predictions will vary. However, after steps 1 and 2, students should predict that the current in the circuit increases as more parallel branches are added. Their predictions should also quantify the change. For example, with three branches, the current will be three times the original value.

Analyze and Conclude

5. Student tables will vary.
6. The resistance decreases with the addition of more parallel branches.

Physics Lab

Sample Data

Data will vary depending on the type of light bulbs used. The sample data is for two 6.3-V bulbs.

Step	Description
3	Both bulbs go out
4	5.20 V
5	2.60 V and 2.60 V
6	150 mA everywhere
8	300 mA
9	2.76 V everywhere
10	170 mA, 2.76 V, other bulb brighter
11	170 mA, 2.76 V, other bulb brighter

Analyze

Note: All answers will depend on individual student data.

1. $R = \dfrac{V}{I}$

$= \dfrac{5.20 \text{ V}}{0.150 \text{ A}}$

$= 34.7 \ \Omega$

2. $R = \dfrac{V}{I}$

$= \dfrac{2.60 \text{ V}}{0.150 \text{ A}}$

$= 17.3 \ \Omega$

3. The sum of the individual resistances of each lightbulb adds up to the total resistance in the series circuit of the pair of lightbulbs.
4. The total potential difference of the pair of lightbulbs is the sum of potential differences of the individual lightbulbs.

5. $R = \dfrac{V}{I}$

$= \dfrac{2.76 \text{ V}}{0.170 \text{ A}}$

$= 16.2 \ \Omega$

This value is close to the calculated resistance of the bulb in the series circuit.

6. Because the potential difference is constant, as the other bulb is removed, the resistance in the circuit decreases and the current increases.

Conclude and Apply

1. In a series circuit, the current is the same, V_{source} equals the total of individual voltage drops, and total resistance equals the sum of individual resistances.
2. In a parallel circuit, the potential difference is the same everywhere, and the total current is equal to the sum of the currents going through each resistance.

Going Further

Data will still confirm statements made in Conclude and Apply.

Real-World Physics

1. Houses are wired in parallel. As demonstrated in step 9, the voltage in each parallel branch is the same as the circuit voltage.
2. The resistance in the house wiring acts like a series load connected in the parallel household circuits. As the device turns on, more current is necessary to start the motor. This causes the current going through other devices to momentarily decrease.

Answer Key

Chapter 23 Study Guide

Series and Parallel Circuits

Vocabulary Review

1. h
2. e
3. i
4. g
5. b
6. c
7. d
8. a
9. k
10. f
11. j
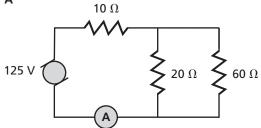
Section 23.1
Simple Circuits
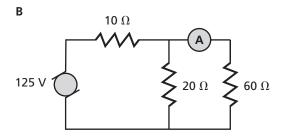
1. b
2. c
3. d
4. a
5. a
6. b
7. b
8. The circuit's electric energy source raises the potential by an amount equal to the potential drop produced when the current passes through the resistors.
9. Multiply the current in the circuit by the resistance of the individual resistor.
10. A series circuit is used as a voltage divider.
11. A voltage divider produces a voltage source of desired magnitude from a higher-voltage battery.
12. The resistance of a photoresistor depends on the amount of light that strikes it. A photoresistor is made a material that naturally has a higher resistance in the dark.
13. A circuit that includes a photoresistor is used in a light meter. The electronic circuit detects the potential difference and converts it to a measurement of illuminance.
14. b
15. b
16. c
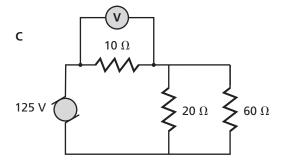
17. d
18. a

Section 23.2
Applications of Circuits

1. true
2. thickness
3. closes
4. true
5. parallel
6. large
7. First draw a schematic of the circuit. Then reduce the problem to a set of series circuits and a set of parallel circuits. Combine the resistances of the parallel circuits into one circuit, and calculate the single equivalent resistance that can replace them. That leaves only a series circuit. Add the resistors in series to calculate the equivalent resistance.
8. a
9. **A**

B

C

10. voltmeter
11. ammeter
12. high
13. low
14. series
15. parallel
16. ammeter
17. high, parallel
18. voltmeter
19. resistance
20. ammeter
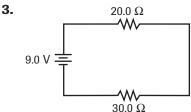
Section 23-1 Quiz

1. The equivalent resistance is the sum of all the individual resistances along the series circuit. To calculate equivalent resistance in a series circuit, add all the individual resistances of the resistors ($R.... = R_A + R_B ...$).

2. A voltage divider is a series circuit used to produce a voltage source of desired magnitude from a higher-voltage battery. To create a voltage divider, a circuit designer would connect two resistors in a series circuit with the battery. The desired voltage is the voltage drop that can be measured across the second resistor. The values of the two resistors would be chosen based on the voltage of the battery and the desired voltage.

3. $R = R_A + R_B + R_C$
   $R = 25 \ \Omega + 30 \ \Omega + 40 \ \Omega = 95 \ \Omega$

   $I = \dfrac{V}{R} = \dfrac{6.0 \ V}{95 \ \Omega} = 0.063 \ A$

4. $\dfrac{1}{R} = \dfrac{1}{R_A} + \dfrac{1}{R_B} + \dfrac{1}{R_C}$

   $\dfrac{1}{R} = \dfrac{1}{25 \ \Omega} + \dfrac{1}{30 \ \Omega} + \dfrac{1}{40 \ \Omega}$

   $R = \dfrac{600}{59} \ \Omega$

   $I = \dfrac{V}{R}$

   $I = \dfrac{6.0 \ A}{\left(\dfrac{600}{59} \ \Omega\right)} = 0.6 \ A$
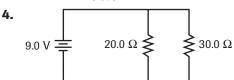
Section 23-2 Quiz

1. When a short circuit occurs, the electricity is traveling along a shorter path because a sizable part of the circuit has been cut out. There is a higher-current intensity in the part of the circuit that remains. A fuse is a short piece of metal that melts when too much current passes through it. The fuse acts as a safety device by preventing this high current flow from continuing and possibly causing an electrical fire.

2. An ammeter measures current in any part of a circuit. To use an ammeter, place it in series in the circuit in the place where you want to measure the current. A voltmeter measures the voltage drop across a resistor. Connect the voltmeter in parallel to the resistor to measure the voltage drop.

3.

   $R = R_A + R_B$
   $R = 20.0 \ \Omega + 30.0 \ \Omega = 50.0 \ \Omega$

   $I = \dfrac{V}{R} = \dfrac{9.0 \ V}{50.0 \ \Omega} = 0.18 \ A$

4.
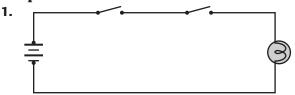
   $\dfrac{1}{R} = \dfrac{1}{R_A} + \dfrac{1}{R_B}$
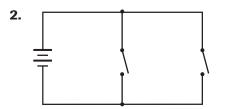
   $\dfrac{1}{R} = \dfrac{1}{20.0 \ \Omega} + \dfrac{1}{30.0 \ \Omega}$

   $R = 12.0 \ \Omega$

   $I = \dfrac{V}{R} = \dfrac{9.0 \ V}{12.0 \ \Omega} = 0.75 \ A$

Chapter 23 Reinforcement

1.

2.
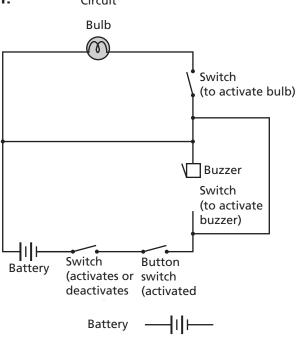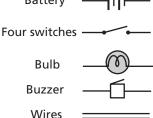
3. a series circuit
4. a parallel circuit

Chapter 23 Enrichment

1.

Circuit

2. The prototype should meet the requirements outlined in the problem. First, the entire alarm system must be able to be activated

and deactivated. Secondly, the alarm must have both a silent alarm and a buzzer alarm. Lastly, the silent alarm and the buzzer alarm must be incorporated into the system so that each can be activated separately or they can be activated simultaneously.

3. This is a parallel circuit. There are two types of warning devices involved—a buzzer and a light. You can operate the circuit so that only the buzzer sounds when an intruder enters. Alternatively, you can create a silent alarm that only turns on the light. You also have the option to activate both.

4. The buzzer and the light are both essentially resistors. Thus, if one was to redraw the circuit, the jagged line that traditionally represents a resistor in circuit diagrams could replace both the buzzer and the light.

5. Since the buzzer and light are considered resistors, the schematic could be redrawn using the resistor symbol in place of the symbol for the bulb and buzzer.

Transparency Worksheet 23-1

Series Circuit

1. The resistances are in a line, not on branches.

2. The equivalent resistance is equal to the sum of the individual resistances.

3. $I = \dfrac{V}{(R_A + R_B + R_C)}$

$= \dfrac{120 \text{ V}}{(30 \ \Omega + 15 \ \Omega + 15 \ \Omega)}$

$= 2 \text{ A}$

4. The sum of the potential drops across all resistors equals the overall potential difference, or $V = (V_A + V_B + V_C)$.

5. $V_A = IR_A = (2.0 \text{ A})(30 \ \Omega) = 60 \text{ V}$

Transparency Worksheet 23-2

Parallel Circuit

1. The resistances are on branches, not in a line.

2. It flows through three paths.

3. $\dfrac{1}{R} = \dfrac{1}{R_A} + \dfrac{1}{R_B} + \dfrac{1}{R_C}$

$= \dfrac{1}{10.0\ \Omega} + \dfrac{1}{5.0\ \Omega} + \dfrac{1}{2.0\ \Omega}$

$= 1.2\ \Omega$

4. The sum of the current through the branches equals the overall current, or $I = I_1 + I_2 + I_3$

5. $I_B = \dfrac{V}{R_B} = \dfrac{60\ \text{V}}{5.0\ \Omega} = 10\ \text{A}$

Transparency Worksheet 23-3

Fuses

1. They are in parallel.

2. It acts as a safety device that melts and opens the circuit if the current exceeds 15 A.

3. $\dfrac{1}{R} = \dfrac{1}{R_A} + \dfrac{1}{R_B} + \dfrac{1}{R_C}$

$= \dfrac{1}{10\ \Omega} + \dfrac{1}{20\ \Omega} + \dfrac{1}{60\ \Omega}$

$= \dfrac{1}{6\ \Omega}$

$R = 6\ \Omega$

4. $I = \dfrac{V}{R} = \dfrac{120\ \text{V}}{6\ \Omega} = 20\ \text{A}$

5. All of the current flows through the fuse because the fuse is connected in series.

6. Yes, the fuse will melt. The 20-A current exceeds the fuse's 15-A rating.

Transparency Worksheet 23-4

Combined Series/Parallel Circuits

1. $R_T = 5.0\ \Omega + 35\ \Omega = 40\ \Omega$

2. $I = \dfrac{V}{R} = \dfrac{120\ \text{V}}{40\ \Omega} = 3\ \text{A}$

3. No, the fuse will not melt. The fuse's 10-A rating exceeds the 3.0-A current.

4. $R_T = 5.0\ \Omega + 35\ \Omega + 5.0\ \Omega = 45\ \Omega$

5. $I = \dfrac{V}{R} = \dfrac{120\ \text{V}}{45\ \Omega} = 2.7\ \text{A}$

6. No, the fuse will not melt. The fuse's 10-A rating exceeds the 2.7-A current.

7. $\dfrac{1}{R_P} = \dfrac{1}{35\ \Omega} + \dfrac{1}{5.0\ \Omega}$

$R_P = 4.4\ \Omega$

$R_T = 4.4\ \Omega + 5$

8. $I = \dfrac{V}{R} = \dfrac{120\ \text{V}}{9.4\ \Omega} = 13\ \text{A}$

9. Yes, the fuse will melt. The 13-A current exceeds the fuse's 10-A rating.

10. Possible answers: Decrease the voltage. Increase the resistance. Both will decrease the current.

Chapter 23 Chapter Assessment

Series and Parallel Circuits

Understanding Physics Concepts

1. a

2. b

3. b

4. c

5. c

6. a

7. true

8. true

9. false

10. true

11. true

12. h

13. b

14. a

15. e

16. c

17. g

18. f

19. d

20. voltage drops

21. resistance

22. the same

23. reciprocal

24. *I*

25. voltmeter

26. complete

27. sum

28. switches

29. potential difference

30. parallel
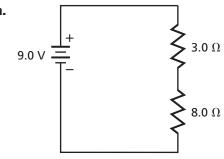
Thinking Critically

1. As the number of parallel branches is increased, the overall resistance of the circuit decreases.

2. The electric wiring uses parallel circuits, so the current in one circuit does not depend on the current in any other circuit.

3. It is a combination series-parallel circuit. Resistors B and C are in series, and A, D, and E, which have the same potential difference across them, are in parallel.

4. An ammeter is connected in series. Its low resistance does not affect the current. If a voltmeter were substituted for the ammeter, the high resistance of the voltmeter would decrease the current.

5. In the bathroom and kitchen, there is plumbing. If an appliance in use touches a cold water pipe or a sink or tub full of water, it could create another current path through a person. A ground-fault interrupter detects the small difference in current this would cause and opens the circuit, preventing electric shock.

6. Because the appliances are connected in parallel, each additional appliance that is turned on reduces the equivalent resistance in the circuit and causes the current to increase.

7. When you connect additional devices in series, the line current decreases; when devices are connected in parallel, the line current increases.

8. When you connect additional devices in series, the line current decreases; when devices are connected in parallel, the line current increases.

9. If one device fails, the current in the whole circuit ceases. Strung Christmas lights are a good example of this phenomenon.

10. Yes, in a parallel circuit, the voltage drop across all devices connected to the same two points in the circuit must be the same.

11. The current drawn by that new device is simply added to the total current of the circuit.

12. a. If one device failed, current would cease throughout the entire household circuit.
    b. The currents and voltages in the other devices would be reduced.

13. Voltmeter have a high resistance in order to cause the smallest possible change in currents and voltages in a circuit.

Applying Physics Knowledge

1. a.

   b. $R = R_1 + R_2$
   $= 3.0 \ \Omega + 8.0 \ \Omega$
   $= 11.0 \ \Omega$

   c. $I_1 = \dfrac{V}{R_1 + R_2}$
   $= \dfrac{9.0 \text{ V}}{11.0 \ \Omega}$
   $= 0.82 \text{ A}$
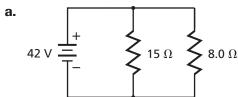
   d. 0.82 A

   e. $V_1 = IR_1$
   $= (0.82 \text{ A})(3.0 \ \Omega)$
   $= 2.5 \text{ V}$

   $V_2 = IR_2$
   $= (0.82 \text{ A})(8.0 \ \Omega)$
   $= 6.6 \text{ V}$

2. a.

   b. $\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$

   $\dfrac{1}{R} = \dfrac{1}{15 \ \Omega} + \dfrac{1}{8.0 \ \Omega}$

   $R = 5.2 \ \Omega$

c. $I = \dfrac{V}{R} = \dfrac{42\text{ V}}{5.2\ \Omega}$

$= 8.1\text{ A}$

d. $I_1 = \dfrac{V}{R_1} = \dfrac{42\text{ V}}{15\ \Omega} = 2.8\text{ A}$

$I_2 = \dfrac{V}{R_2} = \dfrac{42\text{ V}}{8.0\ \Omega} = 5.3\text{ A}$

e. 42 V

3. a. $\dfrac{1}{R_{\text{parallel}}} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$

$\dfrac{1}{R_{\text{parallel}}} = \dfrac{1}{8.0\ \Omega} + \dfrac{1}{8.0\ \Omega}$

$R_{\text{parallel}} = 4.0\ \Omega$

$R = R_1 + R_2 + R_3 =$
$\qquad 4.0\ \Omega + 20.0\ \Omega + 16.0\ \Omega$

$= 4.0 \times 10^1\ \Omega$

$I_{\text{total}} = I_2 = \dfrac{V}{R}$

$= \dfrac{120\text{ V}}{4.0 \times 10^1\ \Omega}$

$= 3.0\text{ A}$

b. $V_1 = I_2 R$

$= (3.0\text{ A})(20.0\ \Omega)$

$= 6.0 \times 10^1\text{ V}$

c. $V_2 = I_2 R$

$= (3.0\text{ A})(16.0\ \Omega)$

$= 48\text{ V}$

d. $V_3 = IR$

$= (3.0\text{ A})(4.0\ \Omega)$

$= 12\text{ V}$

e. $I_1 = \dfrac{V}{R} = \dfrac{12\text{ V}}{8.0\ \Omega}$

$= 1.5\text{ A}$

4. a. $P = I_2 V_1$

$= (3.0\text{ A})(6.0 \times 10^1\text{ V})$

$= 180\text{ W}$

b. $P = I_2 V_2$

$= (3.0\text{ A})(48.0\text{ V})$

$= 140\text{ W}$

c. $P = I_1 V_3$

$= (1.5\text{ A})(12.0\text{ V})$

$= 18\text{ W}$

Chapter 24

Mini Lab

Step 1. Student predictions may vary, however, a correct prediction indicates that the pointed end of the nail will point towards one pole of each permanent magnet and away from the other pole.

Analyze and Conclude

4. The nail consistently points to the same pole of each magnet.

5. Drawings will vary, but the field lines should all go from one pole to the other.

Physics Lab
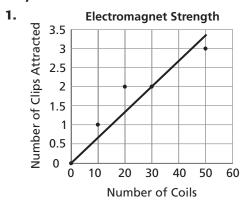
Step 6. Possible procedure:

1. Use a steel nail to try to attract paper clips from a pile (0 coils). Record the number of paper clips attracted.

2. Wrap ten coils of wire around a steel nail and connect both ends of the wire to a 6-V lantern battery. Try to lift as many paper clips as possible. Record the number of clips lifted.

3. Repeat step two with 20, 30 and 50 coils.

Sample Data

Number of Coils	Number of Larger Paper Clips Picked Up
0	0
10	1
20	2
30	2
50	3

Analyze

1.

Electromagnet Strength

Graph: Number of Clips Attracted (y-axis, 0 to 3.5) vs Number of Coils (x-axis, 0 to 60)

2. The wire, paper clips, and current of the wire were controlled. The current may have decreased slightly as the battery was used up.

3. In the sample data this error was not controlled very well. Big paper clips are too massive. It would have worked better to see how many small BBs were picked up.

Conclude and Apply

1. In the sample data, as the number of coils increased, so did the strength of the magnet.

2. An increased current would also increase magnet strength.

3. The length of wire between the electromagnet and the battery.

Going Further

1. Answers will vary.

2. Answers will vary. Adding coils is more cost effective than adding more current.

3. I would vary the electric current.

Real World Physics

1. Increase the current into the electromagnet, because there is little space for more coils.

2. Advantage: If containing a fire requires sealing off a section of the building, then the system can be set electronically to release the doors being held apart.
Disadvantage: If the electric power gets cut off during the disaster, then the system fails.

3. Use an electromagnet to control the hammering of the bell. Wire the bell so that the circuit is closed; the hammer is attracted by the electromagnet. Shifting the hammer opens the circuit, thus demagnetizing the electromagnet. When the hammer returns to its previous place, the circuit closes, the hammer is again attracted by the electromagnet – hence, the continual ringing.

Chapter 24 Study Guide

Magnetic Fields

Vocabulary Review

1. solenoid
2. domain
3. magnetic fields
4. second right-hand rule
5. electric motor
6. third right-hand rule
7. first right-hand rule
8. magnetic flux
9. electromagnet
10. galvanometer
11. polarized
12. armature

Section 24.1 Magnets Permanent and Temporary

1. north-south
2. true
3. repel
4. always
5. true
6. ALNICO
7. Place iron filings around the magnet. They rotate until each is parallel to the magnetic field. The filings become small magnets by induction.
8. Magnetic flux is the number of magnetic field lines that pass through a surface. The flux per unit area is proportional to the strength of the magnetic field. The magnetic flux is most concentrated at the poles of a magnet. This is where the magnetic field strength is the greatest.
9. Outside the magnet, the field lines come out of the north pole, loop around the outside, and enter at the south pole.

10. The field lines become concentrated within the sample. The end of the sample closest to the magnet's north pole becomes the sample's south pole. The sample is attracted to the magnet.

11. The direction of the conventional current is down.

12. The magnetic field is stronger at Point A.

13. Inside the loop, the magnetic field is down, or into the page. Outside the loop, it is up, or out of the page.

14. The left end is the magnetic north pole.

15. Place an iron rod inside the coil, increase the number of loops around the core, or increase the current in the coil.

16. false

17. true

18. false

19. true

20. true

Section 24.2
Forces Caused by Magnetic Fields

1. b

2. a

3. b

4. c

5. The force is down.

6. The force is up.

7. They are attracted.

8. true

9. true

10. false

11. true

12. true

13. magnetic fields

14. wire

15. loop

16. direction

17. down

18. torque

19. current

20. galvanometers

21. proportional

22. voltmeter

23. parallel

24. series

25. multiplier

26. In a cathode-ray tube, electric fields pull electrons off atoms in the cathode. Other electric fields gather, accelerate, and focus the electrons into a narrow beam. Magnetic fields are used to control the motion of the beam across the screen of the tube. The screen is coated with a phosphor that glows when it is struck by the electrons, producing the picture.

27. The force depends on the velocity of the electron, the strength of the field, and the angle between the directions of the velocity and the field.

28. The electron has a negative charge; conventional current has a positive charge.

29. The surface of a computer storage disk is covered with magnetic particles in a film. The disk drive's read/write head is an electromagnet that causes the domains of atoms in the magnetic film to line up in bands. Two bands magnetized with the poles oriented the same direction represent a "0." Two bands with poles oriented opposite directions represent a "1."

30. No current is sent to the read/write head. Instead, the magnetized bands in the disk induce current in the coil in the head. The computer interprets the changes in direction of the current as 0's and 1's.

Section 24-1 Quiz

1. Possible answers: Magnets are polarized, meaning that they have two distinct and opposite ends. Like poles of magnets repel each other; opposite poles attract each other. If a magnet is broken or cut in half, each piece still has two distinct and opposite poles.

2. Magnets produce magnetic fields around them. These magnetic fields exert forces on other magnets, attracting or repelling them.

3. An electric current passing through a wire forms a magnetic field. If the wire is looped to form a coil, the magnetic field is concen-

trated and directed through the coil and produces a magnetic field similar to that of a permanent magnet.

4. Each electron in an atom acts like a tiny electromagnet. A group of neighboring atoms whose electrons' magnetic fields all align in the same direction is called a domain. When all of the domains in a piece of iron are aligned in the same direction, the combined effects form a magnet.

5. The magnetic field that is 4 cm from the wire is weaker than that at 1 cm because the strength of the magnetic field varies inversely with the distance from the wire.

Section 24-2 Quiz

1. A galvanometer can be used as an ammeter by placing a resistor with a resistance smaller than the galvanometer in parallel with the meter. It can be used as a voltmeter by placing a resistor in series with the meter.

2. No, charged particles can move across any region where air has been removed to prevent collisions of the charged particles with air molecules. This occurs inside the cathode-ray tubes used in televisions and computer monitors.

3. $F = ILB = (7.5 \text{ A})(0.23 \text{ m})(0.55 \text{ T}) = 0.95 \text{ N}$

4. $F = qvB = (-1.60 \times 10^{-19} \text{ C})$
   $(2.83 \times 10^7 \text{ m/s})(1.77 \text{ T}) = -8.01 \times 10^{-12} \text{ N}$

Chapter 24 Reinforcement

1. Like poles are facing each other, so the magnets repel each other.

2. (Using a sample mass for one washer)
   $F = ma$
   $= (1.20 \times 10^{-2} \text{ kg})(9.80 \text{ m/s}^2)$
   $= 0.118 \text{ N}$

3. $F = ma$
   $= (4.77 \times 10^{-2} \text{ kg})(9.80 \text{ m/s}^2)$
   $= 0.467 \text{ N}$

4. $F = ma$
   $= (1.089 \times 10^{-3} \text{ kg})(9.80 \text{ m/s}^2)$
   $= 1.07 \times 10^{-2} \text{ N}$

5. At half the distance, the force is four times as great. At one third the distance, the force

is nine times as great. The force is inversely proportional to the square of the distance.

Chapter 24 Enrichment

1. The coil acts like an electromagnet. It pulls the nail downward against the upward pull of gravity. The more current, the stronger the magnetic force.

2. Answers will vary depending upon setup.

3. The graph shows a linear relationship, assuming that the rubber band is not near its elastic limit. The amount of electromagnetic force on the nail is directly proportional to the current.

4. Sample answers: 0.6 cm, 1.1 cm, 1.3 cm

5. The results should be similar to the predictions.

6. Possible answers: Place the nail farther into the coil. Use more turns in the coil. Use a weaker rubber band. Use a larger nail.

Transparency Worksheet 24-1

Magnetic Lines of Force

1. The compasses show the direction of the magnetic field produced by the magnet.

2. They are magnetic field lines. They indicate the strength and direction of the magnetic field.

3. The number of magnetic field lines passing through a surface indicates the magnetic flux.

4. The magnetic flux is most concentrated near the poles of a magnet, which indicates that the magnetic field strength is greatest there.

5. Like poles repel; unlike poles attract.

6. It is near Earth's geographic south pole.

7. It points toward the south pole of the magnet, which is near Earth's geographic north pole.

8. It is strongest near the poles.

Transparency Worksheet 24-2

Right-Hand Rules

1. The first right-hand rule is represented.

2. It points in the direction of current flow.

3. They point in the direction of the magnetic field.
4. It is an electromagnet.
5. It increases the magnet's strength.
6. The second right-hand rule is represented.
7. The north pole of the magnet is represented by curling the fingers of your right hand around the loops of the coil in the direction of the conventional (positive) current. In other words, the thumb points toward the north pole.
8. The curved fingers point in the direction of current flow.
9. The third right-hand rule is represented.
10. The fingers point in the direction of the magnetic field. The thumb points in the direction of conventional (positive) current flow.
11. The force is represented by the direction that the palm of the hand faces.
12. The force acts in the opposite direction.

Transparency Worksheet 24-3

Magnetic Domains

1. A magnetic domain occurs when the magnetic fields of the electrons in a group of neighboring atoms all align in the same direction.
2. In both, the domains point in random directions.
3. The steel bar can be magnetized; the glass marble cannot.
4. You could magnetize the steel bar or the nail by stroking it with a permanent magnet.
5. The magnetic domains align with the magnetic field of the magnet, and all line up in the same direction.
6. The impact can jumble the domains, causing the magnet to lose its magnetism.
7. In a temporary magnet, the domains return to their random arrangement after the external field is removed. In a permanent magnet, the iron is alloyed with other substances to keep the domains aligned after the external magnetic field is removed.

Transparency Worksheet 24-4

MagLev Trains

1. It is short for "magnetic levitating train."
2. Like poles of magnets repel each other. The bottom of the train and the track contain magnets or electromagnets that repel each other, which levitates the train.
3. They are electrodynamic, electromagnetic, and inductrack. In the electrodynamic levitation technique, electromagnets on the guideway levitate the car. In the electromagnetic levitation technique, electromagnets on the cars levitate the car. In the inductrack levitation technique, permanent magnets levitate above passive coils.
4. Alternating magnetic fields push and pull the train forward.
5. Since the train does not touch the ground, there is no friction as there is with the wheels of a conventional train.
6. The train is designed to be aerodynamic; that is, to reduce air resistance.

Chapter 24 Chapter Assessment

Magnetic Fields

Understanding Physics Concepts

1. d
2. a
3. a
4. b
5. c
6. true
7. repel
8. a galvanometer
9. half turn
10. true
11. No; if you break a magnet in half, you create two smaller magnets, each with a north pole and a south pole. The magnetic field is a property of the whole material and cannot be separated into components.
12. They are made of ALNICO, an iron alloy that contains aluminum, nickel, and cobalt.

13. Both produce fields that result in forces that affect objects at a distance.

14. A magnetic field line emerges from a magnet at the north pole, loops around, and reenters the magnet at the south pole. It then travels through the interior of the magnet to the north pole, forming a closed loop.

15. The compass needle moves. The needle is magnetized and is thus attracted to or repelled by magnetic fields created by electric currents.

16. He discovered that the force on a current-carrying wire is at right angles to both the direction of the magnetic field and the direction of the current.

17. An electric motor is designed to allow the loop of wire to continue to rotate. This is done using brushes and a split-ring commutator.

18. The rocks are magnetized in different directions depending on when they formed. This shows that Earth's north and south magnetic poles have changed places many times.

Thinking Critically

1. $B = \dfrac{F}{IL} = \dfrac{0.62 \text{ N}}{(6.0 \text{ A})(0.80 \text{ m})} = 0.13 \text{ T}$

2. $F = ILB$
$= (4.00 \text{ A})(0.600 \text{ m})(0.400 \text{ T})$
$= 0.960 \text{ N}$

3. $B = \dfrac{F}{IL} = \dfrac{0.50 \text{ N}}{(12 \text{ A})(2.0 \text{ m})} = 2.1 \times 10^{-2} \text{ T}$

4. $L = \dfrac{F}{IB} = \dfrac{2.4 \text{ N}}{(8.6 \text{ A})(0.66 \text{ T})} = 0.42 \text{ m}$

5. $F = qvB$
$= (-1.60 \times 10^{-19} \text{ C})$
$\quad\quad\quad\quad (3.46 \times 10^{7} \text{ m/s})(0.420 \text{ T})$
$= -2.33 \times 10^{-12} \text{ N}$

6. A magnet has electrons whose domains are aligned. If the domains of the electrons are not aligned, they cancel each other out.

7. Like charges repel and unlike charges attract. Like poles also repel and unlike poles attract.

8. Hold the ends of the magnets near each other. The north pole of the labeled magnet attracts the south pole of the other magnet and repels the north pole.

9. According to the right-hand rule, the direction of the field above the wire is south to north. The direction of the field below the wire is north to south.

10. Without the current, there is no magnetic force. Therefore all of the objects attracted by the electromagnet are released.

11. Jarring the magnet may knock some domains out of alignment, causing their fields to cancel each other out.

Applying Physics Knowledge

1. Earth's magnetic field deflects electrically charged particles from the Sun into regions around Earth's poles. These regions are called Van Allen belts. When the charged particles escape from the belts, they collide with oxygen and nitrogen atoms in Earth's atmosphere. This causes them to release energy in the form of light.

2. Wrap one of the lengths of wire tightly around the nail. Connect one end of the wrapped wire to the switch, and connect the switch to one terminal of the battery. Connect the other end of the wrapped wire to the other terminal of the battery.

3. When the circuit is completed, the current flowing through the wire causes the coil of wire around the nail to produce a magnetic field. The loops of wire form a magnetic field in the wire, strengthening the field. The iron has less opposition to magnetic fields than air or a vacuum and acts as a conduit for the force.

4. Wrap more wire around the nail.

5. Wrap as much wire as possible around the speaker cones. The longer the wire and the larger the number of turns, the greater the force and the louder the sound produced. Also, design the amplifier to carry as much current as possible. The higher the current, the greater the force and that also increases the sound.

6. $I = \dfrac{V}{R}$

$= \dfrac{120 \text{ V}}{6.0 \text{ }\Omega}$

$= 2.0 \times 10^1$ A

$B = \dfrac{F}{IL}$

$= \dfrac{0.50 \text{ N}}{(2.0 \times 10^1 \text{ A})(0.40 \text{ m})}$

$= 0.063$ T

7. $F = qvB = ma$

$a = \dfrac{qvB}{m}$

$= \dfrac{(1.6 \times 10^{-19} \text{ C})(1.0 \times 10^5 \text{ m/s})(5.5 \times 10^{-5} \text{ T})}{1.67 \times 10^{-27} \text{ kg}}$

$= 5.3 \times 10^8$ m/s^2

Chapter 25

Mini Lab

Analyze and Conclude

3. Turning the crank faster makes the lamp brighter.

4. When motors are connected, one acts as a generator and the other acts as a motor.

Physics Lab

Sample Data

Data will vary depending on types of coils used. Sample data is included.

Number of primary coils	1250
Number of secondary coils	200
Step 3 Observation	Spark; jump in voltage
Step 4 Observation	Light goes on and off
Step 5 Observation	No light
Step 6 Observation	Bulb lights dimly
Step 7 Coil Volts	Primary = 10.0 V Secondary = 1.1 V
Step 8 Observation	Bulb gets dimmer; voltage decreases
Step 9 Iron Core	Warmed

Analyze

1. Answers will vary. Sample data:

$\dfrac{200 \text{ turns}}{1250 \text{ turns}} = 0.16$

2. Answers will vary. Sample data:

$\dfrac{1.1 \text{ V}}{10.0 \text{ V}} = 0.11$

3. They are within experimental error.

4. Step down, voltage is decreased.

Conclude and Apply

1. As long as the DC current is pulsating in the primary coil, it will induce current in the secondary coil.

2. The spark shows there is a high voltage.

3. The iron core helps concentrate the magnetic field that produces the induction.

4. The iron core gets hot because it is not always easy to change fields, and some of the energy that should have been used to change the fields produces thermal energy.

Going Further

In order to induce an electric current, the magnetic field must change.

Real-World Physics

Transformers step up the voltage to transport electrical current from the power station to substations. This allows a more efficient transport of electric current. Then step-down transformers reduce the voltage coming into our homes.

Study Guide

Electromagnetic Induction

1. Lenz's law

2. electromotive force

3. step-down transformer

4. mutual inductance

5. effective voltage

6. fourth right-hand rule

7. electromagnetic induction

8. step-up transformer

9. primary coil

10. average power

Section 25.1
Electric Current From
Changing Magnetic Fields

1. c
2. c
3. a
4. b
5. d
6. c
7. a
8. d
9. d
10. *EMF*, electromotive force, is the potential difference across a wire moving in a magnetic field.
11. The induced *EMF* can be increased by increasing the number of loops of wire in the armature.
12. As the armature of the electric generator turns, the wire loops cut through the magnetic field lines, inducing *EMF*.
13. The induced *EMF* varies as the frequency of the sound varies.
14. In a microphone, a diaphragm is attached to a coil of wire that is free to move in a magnetic field. Sound waves vibrate the diaphragm, which moves the coil in the magnetic field. The motion of the coil induces an *EMF* across the ends of the coil.

Section 25.2
Changing Magnetic Fields
Induce *EMF*

1. true
2. harder
3. the change in the field
4. opposes
5. current
6. increases
7. magnetic field lines
8. EMF
9. self-inductance
10. larger
11. constant
12. zero

13. decreases
14. work
15. energy
16. electric field
17. a
18. d
19. b
20. b
21. d
22. d
23. d
24. d
25. <
26. >
27. <
28. =
29. >
30. <
31. >

32. **a.** $V_p = V_s\left(\dfrac{N_s}{N_p}\right)$

$$= (60.0 \text{ V})\dfrac{4000 \text{ turns}}{150 \text{ turns}}$$

$$= 1.60 \times 10^3 \text{ V}$$

b. $I_s = \dfrac{V_s}{R_s}$

$$= \dfrac{1600 \text{ V}}{1200 \text{ }\Omega}$$

$$= 1.33 \text{ A}$$

c. $I_p = \dfrac{I_s V_s}{V_p}$

$$= \dfrac{(1600 \text{ V})(1.33 \text{ A})}{60.0 \text{ V}}$$

$$= 35.6 \text{ A}$$

d. step-up transformer

Section 25.1 Quiz

1. The amount of current produced depends on the velocity of the wire, the length of the wire, the magnetic field, and the resistance of the wire.
2. Electromagnetic induction is the process of generating current through a circuit by moving a conductor through a magnetic field, or moving a magnetic field across a conductor.

3. a. $EMF = BLv$
$$= (5.0 \times 10^{-2} \text{ T})(0.42 \text{ m})(12.0 \text{ m/s})$$
$$= 0.25 \text{ V}$$

b. $I = \dfrac{V}{R}$
$$= \dfrac{0.25 \text{ V}}{2.25 \text{ }\Omega}$$
$$= 0.11 \text{ A}$$

4. a. $V_{eff} = \dfrac{\sqrt{2}}{2} V_{max}$
$$= \dfrac{\sqrt{2}}{2}(1.20 \times 10^2 \text{ V})$$
$$= 84.8 \text{ V}$$

b. $I_{eff} = \dfrac{\sqrt{2}}{2} I_{max}$
$$= \dfrac{\sqrt{2}}{2}(1.10 \text{ A})$$
$$= 0.778 \text{ A}$$

Section 25.2 Quiz

1. The *EMF* generated when a current-carrying wire moves in a magnetic field.

2. Self-inductance is when an *EMF* is induced in a wire carrying changing current .

3. In a step-up transformer, the secondary voltage is higher than the primary voltage. In a step-down transformer, the primary voltage is higher than the secondary voltage.

4. a. $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$
$$V_s = \dfrac{N_s V_p}{N_p}$$
$$= \left(\dfrac{1780 \text{ turns}}{400 \text{ turns}} \right)(350.0 \text{ V})$$
$$= 1558 \text{ V}$$

b. $\dfrac{V_p}{V_s} = \dfrac{350.0 \text{ V}}{1558 \text{ V}}$
$$= 0.2246$$

c. $I_s = \left(\dfrac{V_p}{V_s} \right) I_p$
$$= \left(\dfrac{350.0 \text{ V}}{1558 \text{ V}} \right)(15.0 \text{ V})$$
$$= 3.37 \text{ A}$$

Reinforcement

1. $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$
$$N_s = N_p \left(\dfrac{V_s}{V_p} \right)$$
$$= (200 \text{ turns}) \left(\dfrac{25,000 \text{ V}}{120 \text{ V}} \right)$$
$$= 4.2 \times 10^4 \text{ turns}$$

2. $I_s = I_p \left(\dfrac{V_p}{V_s} \right)$
$$= (15 \text{ A}) \left(\dfrac{120 \text{ V}}{25,000 \text{ V}} \right)$$
$$= 0.072 \text{ A}$$

3. $R = \dfrac{V}{I}$
$$= \dfrac{120 \text{ V}}{15 \text{ A}}$$
$$= 8.0 \text{ }\Omega$$

4. $R = \dfrac{V}{I}$
$$= \dfrac{25,000 \text{ V}}{0.072 \text{ A}}$$
$$= 3.5 \times 10^5 \text{ }\Omega$$

5. $1 : 210$ or $4.8 \times 10^{-3} : 1$

6. $1 : 210$ or $4.8 \times 10^{-3} : 1$

7. $210 : 1$

8. $2.3 \times 10^{-5} : 1$

Enrichment

1. As the number of loops increases, the deflection seen on the voltmeter increases.

2. Increasing the speed of the magnet increases the deflection seen on the voltmeter.

3. As the direction changes, the voltage reading drops to zero and then increases again.

4. The voltage readings should be similar if the relative speeds are similar.

5. As the speed of the loops increases, the deflection read on the voltmeter increases.

6. As the direction of the loops changes, the voltage reading drops to zero and then increases again.

Answer Key

Transparency Worksheet 25-1

Electric Motor/DC Generator

1. Electric energy is running the system and the battery is its source.
2. The armature is the rod with wire coiled around it. It is acted on by the magnetic field created by the field magnet, since parts of the wire have current running through them perpendicular to the magnetic field.
3. The north and south poles of the armature will reverse.
4. The source of the energy for the generator is the mechanical energy from the crank.
5. Electric current is generated by electromagnetic induction, as the wire is moved through a magnetic field.
6. The voltage, or *EMF*, produced by the system would increase.

Transparency Worksheet 25-2

AC Generator

1. The wire is moving perpendicular to the field.
2. The maximum amount of current, I_{max}, moves through the wire.
3. The wire is moving parallel to the field.
4. Only the component of motion that is perpendicular to the field induces a current. When the motion of the wire is perpendicular to the field, the maximum amount of current is induced. When the wire moves parallel to the field, there is no motion perpendicular to the field, so there is no current.
5. The maximum amount of current is carried, $-I_{max}$.

Transparency Worksheet 25-3

Lenz's Law

1. A downward current is induced. The third right-hand rule is used.
2. The force exerted by the magnetic field opposes the original motion of the wire.

3. Lenz's law states that the direction of the induced current is such that the magnetic field resulting from the induced current opposes the change in the field that caused the induced current.
4. The armature will be easy to turn. When the generator produces a small current, the opposing force on the armature is also small.
5. When a mechanical load is placed on a motor, the rotation of the motor slows. The slowing decreases the back-*EMF* and allows more current to be carried through the motor.

Transparency Worksheet 25-4

Step-Up and Step-Down Transformers

1. The voltage is doubled if the number of turns on the secondary coil are double the number on the primary coil $\left(\dfrac{V_p}{V_s} = \dfrac{N_p}{N_s} \right)$.
2. The voltage is doubled.
$$V_s = \dfrac{(V_p)(N_s)}{N_p}$$
$$= \dfrac{(120 \text{ V})(4 \text{ turns})}{2 \text{ turns}}$$
$$= 240 \text{ V}$$
3. The voltage across the secondary circuit would be less than 350 V, but without knowing either the number of turns on each coil or the currents in the coils, you cannot calculate the specific voltage.
4. The current in the secondary circuit would be greater than 40A, but without knowing either number of turns on each coil or the voltages, you cannot calculate the specific current.
5. Ohm's law ($V = IR$) holds true in a single circuit. In this instance, the currents being compared are actually in two different circuits.

Chapter 25 Assessment

1. step-up transformer
2. step-down transformer

3. average power
4. fourth right-hand rule
5. electromagnetic induction
6. electromotive force
7. primary coil
8. electric generator
9. transformer
10. eddy current
11. perpendicular
12. mechanical
13. true
14. true
15. true
16. step-up
17. greater
18. true
19. a
20. c
21. c
22. a
23. c

Thinking Critically

1. $EMF = BLv$
$$= (4.42 \times 10^{-4} \text{ T})(25.5 \text{ m})(14.4 \text{ m/s})$$
$$= 0.162 \text{ V}$$

2. $V_{\text{eff}} = \dfrac{\sqrt{2}}{2} V_{\text{max}}$
$$= \dfrac{\sqrt{2}}{2}(5.00 \times 10^2 \text{ V})$$
$$= 354 \text{ V}$$

3. a. $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$
$$V_s = V_p\left(\dfrac{N_s}{N_p}\right)$$
$$= (110 \text{ V})\left(\dfrac{1500 \text{ turns}}{350 \text{ turns}}\right)$$
$$= 470 \text{ V}$$

b. $I_p = I_s\left(\dfrac{V_s}{V_p}\right)$
$$= (15.0 \text{ A})\left(\dfrac{1500 \text{ turns}}{350 \text{ turns}}\right)$$
$$= 64.3 \text{ A}$$

c. $P_{\text{output}} = V_s I_s$
$$= (15 \text{ A})(470 \text{ V})$$
$$= 7.1 \times 10^3 \text{ W}$$
$P_{\text{input}} = V_p I_p$
$$= (110 \text{ V})(64.3 \text{ A})$$
$$= 7.1 \times 10^3 \text{ W}$$

4. $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$
$$N_s = N_p\left(\dfrac{V_s}{V_p}\right)$$
$$= (725 \text{ turns})\left(\dfrac{555 \text{ V}}{120.0 \text{ V}}\right)$$
$$= 3350 \text{ turns}$$

5. According to Lenz's law, the induced magnetic field exerts a force that opposes the rotation of the armature, thus slowing it down. But when the armature slows down, the induced magnetic field will be reduced, thus reducing the opposing force. As long as the force turning the armature does not change, it will always be greater than the opposing force from the induced current, and the armature will not stop turning.

6. In this ideal transformer, the secondary voltage (240 V) is four times greater than the primary voltage (60 V), so the secondary current must be one fourth of the primary current. Thus the power ($P = IV$) is the same in both coils, and energy is conserved.

7. The thermal energy must be produced by collisions among electrons and atoms in the wire. There are also so-called non-load losses that arise from magnetizing and de-magnetizing the transformer's core.

8. Turning off the motor suddenly changes the magnetic field in the motor, which produces a back-*EMF*. Because the change is sudden, the back-*EMF* can be large enough to cause a spark to jump. The spark does not persist because the back-*EMF* disappears once the magnetic field stops changing.

Applying Physics Knowledge

1. The galvanometer registers a current produced in the loop of wire as the magnetic field of the magnet crosses the conducting wire.

2. The voltage is zero. No current is induced because the conductor is not moving through the magnetic field.

3. Since *EMF* is directly proportional to magnetic field strength, it doubles.

4. The electric motor changes electrical energy into mechanical energy, whereas the generator changes mechanical energy into electrical energy.

5. The heavy current required to start a motor causes a voltage drop across the wires that carry current to the motor. In turn, the voltage across the motor drops, along with the voltage of the lights connected in parallel near the motor.

6. If the voltage across the secondary coil before doubling the number of turns in the primary coil is represented as V_{s1} and the voltage across the secondary coil after doubling the number of turns is V_{s2}, then $V_{s2} = V_{s1}/2$.

7. $V = IR$

$EMF = BLv$

$$v = \frac{IR}{BL}$$

$$= \frac{(1.34\times10^{-2} \text{ A})(5.50 \text{ }\Omega)}{(0.250 \text{ T})(1.12 \text{ m})}$$

$$= 0.263 \text{ m/s}$$

8. **a.** $\dfrac{175 \text{ W}}{225 \text{ J/s}} = 0.778$

b. $P = IV$

$V = IR$

$P = I^2R$

$$I = \sqrt{\frac{P}{R}}$$

$$= \sqrt{\frac{175 \text{ W}}{15.0 \text{ }\Omega}}$$

$$= 3.42 \text{ A}$$
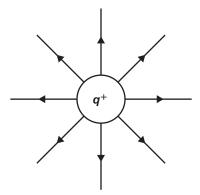
9. $P_{avg} = \dfrac{1}{2}P_{max}$

$P_{max} = (2)(150 \text{ W})$

$= 3.0\times10^2 \text{ W}$
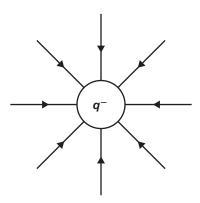
10. $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$

$$\frac{N_p}{N_s} = \frac{35 \text{ V}}{12 \text{ V}}$$

$$= 2.9$$

Art for Answer Key section
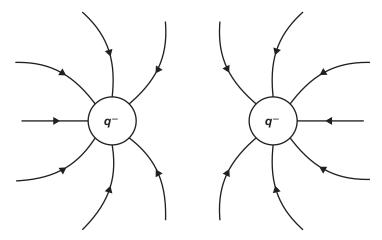
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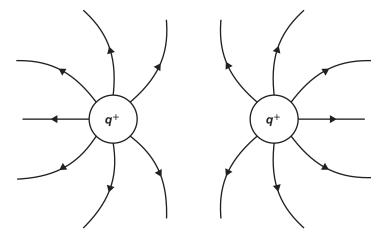
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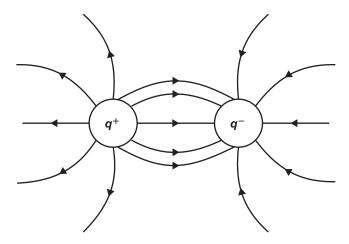
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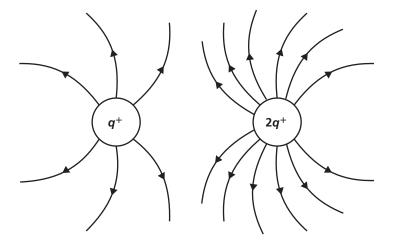
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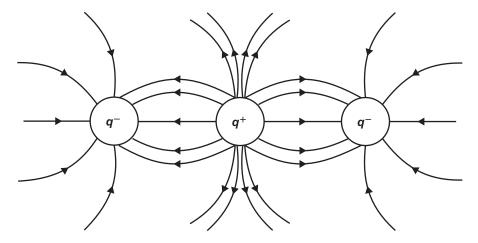
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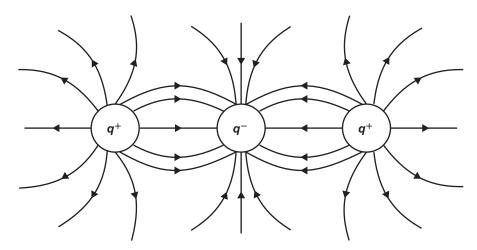
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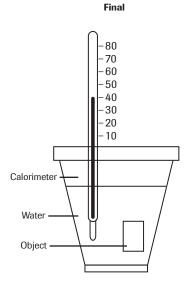
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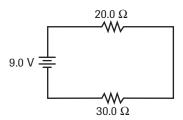

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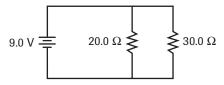
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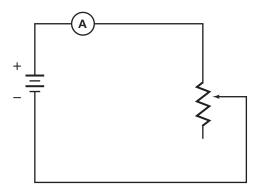[crf_ch23_ta04] Study Guide Question #9--guide

Final

Calorimeter
Water
Object
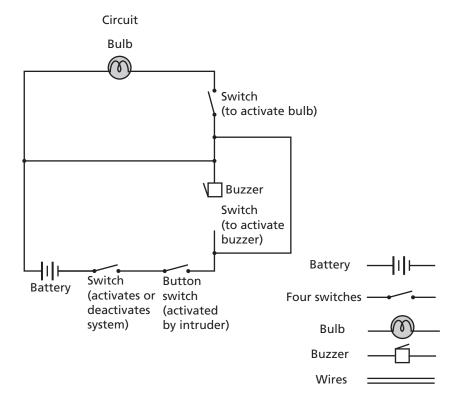
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20.0 Ω

9.0 V

30.0 Ω

[crf_ch23_ta06] Section Quiz Question #4--guide

9.0 V   20.0 Ω   30.0 Ω

Circuit

Bulb

Switch
(to activate bulb)

Buzzer

Switch
(to activate
buzzer)

Battery

Switch
(activates or
deactivates
system)

Button
switch
(activated
by intruder)

Battery

Four switches

Bulb

Buzzer

Wires
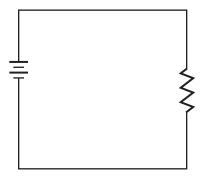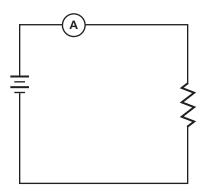
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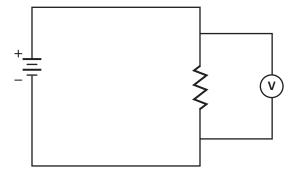
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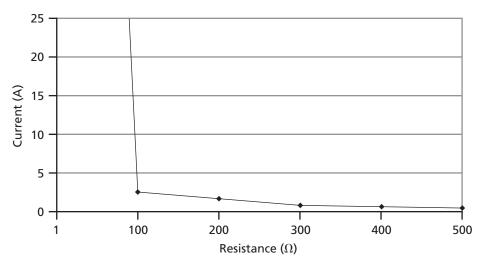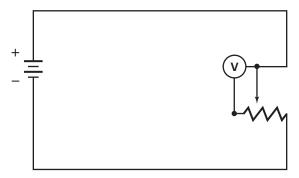
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[crf_ch22_ta12] Reinforcement Results Question #1--guide

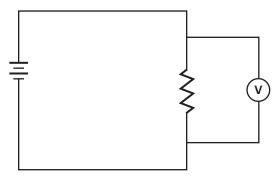| V	R	I
250 V	1 Ω	250 A
250 V	100 Ω	2.50 A
250 V	200 Ω	1.25 A
250 V	300 Ω	0.83 A
250 V	400 Ω	0.62 A
250 V	500 Ω	0.50 A
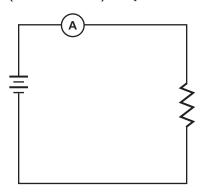
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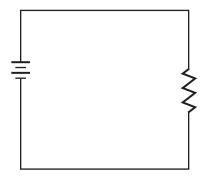[crf_ch22_ta04] Reinforcement Results Question #3--guide

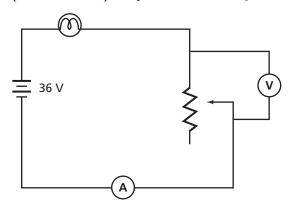[crf_ch22_ta05] Chapter Assessment Question #20--guide

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[crf_ch22_ta08] Chapter Assessment Question #1--guide

[crf_ch22_ta09] Chapter Assessment Question #1--guide

[crf_ch22_ta15] Chapter Assessment Question #15--guide

Length (m)	Current (A)	Voltage (V)	Resistance (Ω)
1	12.7	9	0.7
2	6.4	9	1.4
3	4.3	9	2.1
4	3.2	9	2.8
5	2.6	9	3.5

[crf_ch22_ta16] Chapter Assessment Question #16--guide