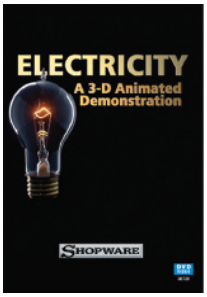


Instructor's Guide

Electricity: A 3-D Animated Demonstration

CIRCUITS

Introduction

This instructor's guide provides information to help you get the most out of *Circuits,* part of the eight-part series *Electricity: A 3-D Animated Demonstration.* The series makes the principles of electricity easier to understand and discuss. The series includes *Electrostatics; Electric Current; Ohm's Law; Circuits; Power and Efficiency; Electricity and Magnetism; Electric Motors;* and *Electric Generators*.

Circuits explores electric circuit theory, as well as how to ensure safety in circuit management.

Learning Objectives

After watching the video program, students will be able to:

- Describe what is needed to complete and manage a circuit
- Outline what causes circuits to fail
- Diagram and describe at least two circuit safety devices
- Explain the factors that influence electric resistance
- Calculate electric resistance
- Identify resistivity substances/materials

Educational Standards

National Science Standards

This program correlates with the National Science Education Standards from the National Academies of Science, and Project 2061, from the American Association for the Advancement of Science.

Science as Inquiry

Content Standard A: As a result of activities in grades 9-12, all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Physical Science

Content Standard B: As a result of their activities in grades 9-12, all students should develop an understanding of:

- Structure of atoms
- Motions and forces
- Conservation of energy and increase in disorder
- Interactions of energy and matter

Science and Technology

Content Standard E: As a result of activities in grades 9-12, all students should develop understanding of:

- Abilities of technological design
- Understandings about science and technology

History and Nature of Science

Content Standard G: As a result of activities in grades 9-12, all students should develop understanding of

- Nature of scientific k nowledge
- Historical perspectives

National Science Education Standards, from the National Academies of Science, and Project 2061 come from the American Association for the Advancement of Science. Copyright 1996 by the National Research Council of the National Academy of Sciences. Reprinted with permission.

English Language Arts Standards

The activities in this instructor's guide were created in compliance with the following National Standards for the English Language Arts from the National Council of Teachers of English.

- Standard 7: Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

- Standard 8: Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standards for the English Language Arts, by the International Reading Association and the National Council of Teachers of English. Copyright 1996 by the International Reading Association and the National Council of Teachers of English. Reprinted with permission.

Mathematics Standards

This program correlates with the Principles and Standards for School Mathematics by the National Council of Teachers of Mathematics.

Problem Solving

Instructional programs from pre-kindergarten through grade 12 should enable all students to:

- Build new mathematical knowledge through problem solving
- Solve problems that arise in mathematics and in other contexts
- Apply and adapt a variety of appropriate strategies to solve problems

Reasoning and Proof

Instructional programs from pre-kindergarten through grade 12 should enable all students to:

- Select and use various types of reasoning and methods of proof

Principles and Standards for School Mathematics by the National Council of Teachers of Mathematics. Published 4/12/2000. Reprinted with permission.

Technology Standards

The activities in this Teacher's Guide were created in compliance with the following National Education Technology Standards from the National Education Technology Standards Project.

Standard 2: Communication and Collaboration

Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others.

Standard 3: Research and Information Fluency

Students apply digital tools to gather, evaluate, and use information.

Standard 4: Critical Thinking, Problem-Solving & Decision-Making

Students use critical thinking skills to plan and conduct research, manage projects, solve problems and make informed decisions using appropriate digital tools and resources.

The National Education Technology Standards reprinted with permission from the International Society for Technology Education. Copyright 2007.

Program Summary

This program presents both the theory of electric circuits and basic practical methods of managing circuits safely. The benefits and dangers of ground circuits are investigated, together with safety devices such as fuses and ground fault interrupters.

Main Topics

Topic 1: Completing a Circuit
This introductory segment discusses what an electric circuit does in relation to the flow of electricity. It also speaks to how circuits should be managed to ensure they function safely.

Topic 2: Fuses
This segment examines the fuse, a safety device that causes controlled circuit failure.

Topic 3: Circuit Breakers
In this segment, students explore the circuit breaker, another electrical safety device that, like the fuse, controls the failure of electric circuits.

Topic 4: Ground Circuits
Here, students study the phenomena associated with ground circuits, particularly the relationship between an electric charge and the ground.

Topic 5: Ground Faults
This section explains the dangers associated with electricity, particularly electric appliances, and how these dangers may be averted if, for example, wires and appliance receptacles are properly grounded.

Topic 6: Ground Fault Interrupters
Students learn how ground fault interrupters function to help protect against the possibility of accidentally grounding an electrical circuit through the body.

Topic 7: Resistance
Here, students learn — through a water flow model — how electricity meets resistance.

Topic 8: Electrical Resistance
In this final segment, students discover the factors that influence electric resistance, as well as learn how to calculate electric resistance, based on an equation derived from the proportionalities that influence it.

Fast Facts

- A potential for electric current flow only exists if there is an electric potential difference between two objects or regions.
- A badly managed electric circuit can result in unwanted and dangerous work, like overloading and overheating conducting wires and connectors.
- A rating indicates how much current a fuse can manage: if the current exceeds this rating, the fuse's strip or wire will melt … and then blow.
- A circuit breaker quickly cools and can be reset, unlike a fuse, which once overheated, blows and must be thrown away.
- The earth is an enormous reservoir of electric charge.
- When a region of the atmosphere develops a large positive charge, electrons flow from the ground up into the atmosphere. In this situation, lightning strikes up, not down.
- Properly wired ground circuits can channel away stray electricity and help protect someone's safety.
- A ground fault interrupter is a form of circuit breaker; it detects tiny amounts of electricity draining away from a circuit and acts instantly to break the circuit.
- Like resistance to water flow, resistance to electric current flow also produces waste heat.
- Movement meets resistance … and so does the movement of electricity.

Vocabulary Terms

AC current: Alternating electrical current; AC is short for alternating current. The direction of the current flowing in a circuit is constantly being reversed back and forth.

bi-metal: Refers to an object that is composed of two separate metals joined together.

circuit: An electrical device in which charge can come back to its starting point and be recycled rather than getting stuck in a dead end.

circuit breaker: An automatic switch that stops the flow of electric current in a suddenly overloaded or otherwise abnormally stressed electrical system.

conductor: A material (like a metal) through which electricity and heat flow easily.

connector: The part of a cable that plugs into a port or interface to connect one device to another.

current: The flow of electricity, commonly measured in amperes.

DC current: Direct electrical current (continuous current).

electric resistance: A material's opposition to the flow of electric current.

electron: A negatively charged particle that is a small part of an atom.

fuse: A safety device that protects electrical appliances by preventing too much electricity flowing into them.

ground circuit: A circuit can be completed between any level of voltage and the earth, or ground; ground is the reference point in an electrical circuit from which other voltages are measured.

ground fault: An electrical condition in which a short circuit develops between an energized conductor and a ground potential.

ground fault interrupter: A safety device that disconnects power from a circuit when a potentially dangerous electrical condition exists.

immersion heater: An electrical water heater inserted into a hot water cylinder.

load: A device that consumes electrical power and is connected to a source of electricity.

magnetic field: The region around a magnet where the magnetic force acts.

potential difference: Work that must be done against electrical forces to move a unit charge from one point to the other.

proportionality: A ratio of two quantities that is constant.

resistance: The characteristic of materials to oppose the flow of electricity in an electric circuit.

resistivity: The capacity for or tendency toward resistance.

short circuit: A circuit that does not function because charge is given a low-resistance "shortcut" path that it can follow, instead of the path that makes it do something useful.

terminal: A conductor attached at the point where electricity enters or leaves a circuit, e.g., on a battery.

viscous: Having relatively high resistance to flow (such as a thick liquid).

volt: A unit of electromotive force or potential difference.

voltage: A measure of the pressure under which electricity flows.

voltmeter: Electronic meter used to measure voltage; used to measure the electric potential difference between two points in an electric circuit.

Pre-Program Discussion Questions

1. What does an electrical circuit do?
2. What is a short circuit?
3. Describe the role a circuit breaker might have.
4. How might voltage and the ground be related?
5. Describe the term "grounded" in terms of electricity.

Post-Program Discussion Questions

1. When a circuit is "badly managed," what happens?
2. How does a circuit fail?
3. What is important about devices such as a fuse and a ground fault interrupter?
4. Describe the counter theory of the current flow convention related to the relationship between the ground and the atmosphere.
5. How does electric current resistance compare to a water flow model?

Individual Student Projects

Measuring Resistivity
Students can measure the resistivity of several different metal wires.

Resistivity: Where it Resides and at What Level
Students can research the resistivity of a variety of materials. A materials sampling is found at "The Physics Classroom Tutorial" (http://www.glenbrook.k12.il.us)

Exploring the Fuse
Students conduct experiments that allow them to observe and document how a fuse functions and to recognize the physics principles associated with them. Find several activities at (be sure to also reference books included in this guide's Additional Resources section).

- Experiments to Explore Electricity: www.dukesafety.com/schools/PDFs/8011_Duke_S_71130_ExpExpElectricity_TLPG_v4_0807.pdf
- Electric Circuits: www.delta-education.com/science/dsm/samples/ElectCircuitsLink1.pdf

Group Activities

Diagramming Safety Devices
Students apply their knowledge of electrical safety devices by diagramming one or more of those introduced in the film. Accompanying the diagrams is a physics rationale or an explanation of how the device functions and why it does so.

Building a Circuit Breaker
Students can construct a circuit breaker to recognize and explain how it functions.

Safety Devices in Real Life
Students can invite an electrical engineer or electrician to the class to demonstrate electrical safety devices and to demystify any myths associated with them.

Internet Activities

How Interactive Can Circuits Be?
Students review and rate several sites exploring circuits and their various safety devices. Then, they create a "storyboard" representing a site they would create to best educate students and others on

circuits and relevant safety mechanisms, along with references to fuses, circuit breakers, ground fault interrupters, etc. If students have the tech and design capability, they might create and launch a site. Sites that jumpstart exploration include:

- Circuit: www.bcae1.com
- Circuits: www.explorelearning.com/index.cfm?method=cResource.dspView&ResourceID=398
- Circuit Breaker: www.bcae1.com/cirbrakr.htm
- Electricity Explained: www.furryelephant.com/content/electricity/lessons

How They Work

Students log on to "How Circuit Breakers Work" at www.howstuffworks.com. Using this article as a model, students write a similar online article to describe how fuses or ground fault interrupters function. Or, they can write an article about circuit breakers, but in a different style. Students may pitch the article to "How Stuff Works" or simply create a "how to" packet on electrical safety devices to distribute to the class.

Online Quizzing

Students test their mathematical knowledge by taking online resistance quizzes (calculations, problem solving). Find a sample quiz at Resistance and Resistivity (homepage.mac.com/njaustin/PHYS1420/Quizzes/quiz05.pdf)

Assessment Questions

1: What is the role of the third prong on a 3-prong plug?
- **a) It provides extra power for appliances that need higher voltage.**
- **b) It firmly holds the plug in the outlet.**
- **c) It provides a path to the ground for electricity that may stray from an appliance or product.**

2: _____ refers to a material's ability or inability to conduct electricity.

3: Why will too many electrical devices operated at one time often blow a fuse?

4: One way to be protected from potential shock hazards is by using:
- **a) Voltmeters**
- **b) Circuit breakers**
- **c) Ground fault interrupters**

5: If a fuse has a rating of 5 amps, then:
- **a) it will likely blow**
- **b) it can only operate at a current of 5 amps**
- **c) a current greater than 5 amps will blow the fuse**

6: Resistance varies directly with_____.

7: Resistance to electric current also depends on the _____ area of the conductor.

8: What does it mean for a circuit to be completed?

9: In the resistance equation $R = \rho (L/A)$ what do the letters/symbols represent?

10: Which of the following statements about metals is NOT accurate?
- **a) When heated, all metals expand at the same rate.**
- **b) When heated, all metals expand.**
- **c) Only bi-metals expand when heated.**

Assessment Questions Answer Key

1: What is the role of the third prong on a 3-prong plug?

a) It provides extra power for appliances that need higher voltage.
b) It firmly holds the plug in the outlet.
c) It provides a path to the ground for electricity that may stray from an appliance or product.

A: c
Feedback: The third prong provides a path to ground to protect the equipment and user from electric shock.

2: _____ refers to a material's ability or inability to conduct electricity.
A: Resistivity
Feedback: Resistivity depends on the nature of the conductor. Conductors, semi-conductors, and insulators can be placed on a sliding scale of inherent resistivity. At one end are metals like gold, silver, and copper that have low resistivity and thus conduct electricity well. On the other end are non-metals, like glass, that have high resistivity and thus poorly conduct electricity.

3: Why will too many electrical devices operated at one time often blow a fuse?
A: Too many electrical devices at one time will often blow a fuse because the maximum current has been exceeded.
Feedback: The heart of the fuse is a thin metal strip or wire with a known melting point. The strip or wire will melt when a certain maximum current is exceeded. Proper fuse rating may ensure that the fuse does not blow (meaning it might be able to handle a bit more current).

4: One way to be protected from potential shock hazards is by using:

a) Voltmeters
b) Circuit breakers
c) Ground fault interrupters

A: c
Feedback: Properly wired ground circuits can channel away stray electricity and help protect someone's safety. But they are not a guarantee that someone won't become part of a ground circuit with damaging, perhaps fatal, consequences.

5: If a fuse has a rating of 5 amps, then:

a) it will likely blow
b) it can only operate at a current of 5 amps
c) a current greater than 5 amps will blow the fuse

A: c
Feedback: A fuse will blow if the current is greater than its rating.

6: Resistance varies directly with_____.
A: temperature
Feedback: As temperature drops, resistance decreases, until at a temperature close to absolute zero, some materials become superconductors, with virtually no resistance to current at all.

7: Resistance to electric current also depends on the _____ area of the conductor.
A: cross section
Feedback: Like resistance to water flow, resistance to electric current flow also produces waste heat, heat which is often more readily apparent than the warming by friction of flowing water. Like a pipe's resistance to water flow, a resistance to current flow is also increased as the length of a conductor increases. Electric resistance varies directly with length. You may have noticed that an appliance plugged into a very long extension cord will cause the extension cord to become noticeably warm. Resistance to electric current also depends on the cross section area of the conductor**.**

8: What does it mean for a circuit to be completed?
A: It means that it connects two different levels of electric potential.
Feedback: When a circuit is completed, not only does current flow, the flow of electricity can be managed in order to do effective and useful work, like boiling a cup of water.

9: In the resistance equation R = ρ (L/A) what do the letters/symbols represent?
A: R = resistance (in ohms); ρ = resistivity of the material (ohm-meters); L = length of the conductor/wire (in meters); A = cross section area of the conductor (m^2).
Feedback: The equation is derived from the following: the combination of two proportionalities that influence resistance — resistance varies directly as the length of the conductor and resistance varies inversely as the cross section of the conductor. The resulting proportionality is the equation with the addition of the proportionality constant, which in this case is known as resistivity.

10: Which of the following statements about metals is NOT accurate?
a) When heated, all metals expand at the same rate.
b) When heated, all metals expand.
c) Only bi-metals expand when heated.
A: b
Feedback: All metals expand when heated, but different metals expand at different rates.

Additional Resources

BOOKS

Physics Experiments On File™. Facts on File, 2003. ISBN-10: 0816050430

Electricity and Magnetism, by Kyle Kirkland, Ph.D. Facts on File, 2007. ISBN: 978-0-8160-6112-9

Awesome Experiments in Electricity & Magnetism, by Michael A. DiSpezio. Sterling, 1999. ISBN: 0806998199

Basic Electricity, by Nooger and Neville Van Valkenburgh. Prompt; 1st edition, 1995. ISBN: 0790610418

Electric Circuits, by J. Nilsson (6th edition). Prentice Hall, 1999. ISBN: 0-201-43653-1

Electric Universe: The Shocking True Story of Electricity, by David Bodanis. Crown, 2005. ISBN: 1400045509

Electricity and Magnetism Science Fair Projects: Using Batteries, Balloons, and Other Hair-Raising Stuff (Physics! Best Science Projects), by Robert Gardner. Enslow Publishers, 2004. ISBN: 0766021270

Physics Demonstrations: A Sourcebook for Teachers of Physics, by Julien Clinton Sprott. University of Wisconsin Press; 1st edition, 2006. ISBN: 0299215806

Schaum's Outline of Basic Electricity, 2nd edition, by Milton Gussow. McGraw-Hill, 2006. ISBN: 0071474986

Schaum's Outline of Electric Circuits, by Mahmood Nahvi and Joseph A. Edminister. McGraw-Hill; 4th edition, 2002. ISBN: 0071393072

WEB SITES

All About Circuits
www.allaboutcircuits.com

BBC: Bitesize Revision — Circuit symbols
www.bbc.co.uk/schools/ks3bitesize/science/physics/electricity_3.shtml

BBC: Bitesize Revision — Electric current and circuits
www.bbc.co.uk/schools/ks3bitesize/science/physics/electricity_2.shtml

Classroom of the Future: Electricity and Power in Space
http://iss.cet.edu/electricity

comPADRE: Digital Resources for Physics & Astronomy Education
www.compadre.org

Electrical Safety Foundation International
www.esfi.org/cms/node/8#bookmark

The Energy Story — Chapter 4: Circuits
www.energyquest.ca.gov/story/chapter04.html

Furry Elephant
www.furryelephant.com

How Stuff Works — How Circuit Breakers Work
http://electronics.howstuffworks.com/circuit-breaker.htm

HyperPhysics — Electric Circuits
http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

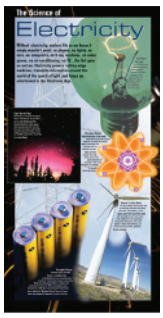
IEEE — Two Button Buzzer Circuit
www.ieee.org/web/education/preuniversity/tispt/ldoorbell.html

Physics.org
www.physics.org

School Physics
http://www.schoolphysics.co.uk

Science Joy Wagon: The Physics Zone — Simple AC Circuit
www.sciencejoywagon.com/physicszone/otherpub/wfendt/accircuit.htm

Additional Resources from www.films.com • 1-800-257-5126



The Science of Electricity Poster

- **17" x 32" Poster**
- **Correlates to National Science Education Standards**
- **Item # 36854**

Recommended for grades 7-12. © 2006

Investigations in Physics: Experiments and Observations

- **DVD/ VHS #6842**
- **Preview clip online**
- **Correlates to educational standards**
- **"Useful in secondary physics classes, especially where hands-on experimentation is limited."**
  —School Library Journal

Designed for basic physics labs, this 9-part series offers an extensive collection of demonstrations and experiments essential to any core physics curriculum. Each program features three related lessons that are supported by tabletop close-ups, computer graphics and animation, re-creations of famous experiments using replicas of original equipment, and simple, concise narration. Some lessons incorporate sophisticated equipment not normally found in schools. Selected demonstrations take viewers to exotic sites to dramatically illustrate fundamental physics principles. The series includes *Equilibrium of Forces • Motion of Bodies and Mechanical Energy • Pressure • Heat • Waves and Sound • Optics • Magnetism and Static Electricity • Electrical Energy • Electric Current* (30 minutes each)

Electricity and Magnetism

- **CD-ROM #10267 (Windows/Macintosh)**
- **Preview clip online**
- **Correlates to the National Science Education Standards developed by the National Academies of Science and Project 2061 Benchmarks for Science Literacy from the American Association for the Advancement of Science.**
- **Includes activity sheets**

Since the early experiments with electricity over two hundred years ago, scientists have made many discoveries that help explain its nature. These discoveries have linked many areas of science including static electricity, electric current, magnetism, and materials. In all areas of our life at home and at school we rely on electricity, which has become a crucial part of modern society. Electricity and Magnetism examines the principles involved and gives students an insight into this fascinating topic, covering such subjects as: Static electricity; Attraction/repulsion; Current electricity and electrical circuits; Measuring electricity—current, voltage, meters; Electrical calculations; Magnetism—materials, fields, rules, Earth's field; Field around a current-carrying wire; Link between electricity and magnetism—induction. © 1999

Electronics and Electrical Engineering, Volume 1

- **DVD/ VHS #36072**
- **Preview clip online**
- **Close captioned**
- **Correlates to educational standards**
- **Includes viewable/printable instructor's guides**

This 20-part series covers everything from basic electrical theory, to electronics troubleshooting, to residential electrical wiring. The series includes • *Electrical Principles* • *Electric Circuits: Ohm's Law* • *Electrical Components, Part I: Resistors, Batteries, and Switches* • *Electrical Components, Part II: Capacitors, Fuses, Flashers, and Coils* • *Electrical Components, Part III: Transformers, Relays, and Motors* • *Electronic Components, Part I: Semiconductors, Transistors, and Diodes* • *Electronic Components, Part II: Operation—Transistors and Diodes* • *Electronic Components, Part III: Thyristors, Piezo Crystals, Solar Cells, and Fiber Optics* • *Electrical Troubleshooting* • *Electronic Troubleshooting* • *The Service Entrance* • *Panelboards* • *Wiring Methods* • *Grounding* • *GFCIs and AFCIs* • *Receptacles and Switches* • *Wiring Light Fixtures* • *Wiring for Appliances* • *Math in Electrical Technology* • *Electrical Safety.* Recommended for high school, technical or vocational school, and training programs. (18-24 minutes each) © 2006

Energy I Video Library

- **DVD #30960**
- **Close captioned**
- **Correlates to educational standards**
- **Includes user guides**

Contains 22 video clips on forms of energy, nuclear energy, electricity, and magnetism:

- Fuel Cells
- Solar Energy
- Potential and Kinetic Energy
- Nuclear Energy Forms
- Nuclear Medicine
- Nuclear Submarines
- Electrical Energy
- The Body Electric
- Electricity Production
- Electromagnetism
- Lodestone
- Energy Production
- Chemical Energy
- Introduction to Nuclear Energy
- Natural Nuclear Reactions
- The Atomic Bomb
- Introduction to Electricity
- Harnessing Electricity
- High Wire Act
- Introduction to Magnetism
- Animal Navigation
- Earth as a Magnet

The Energy I Video Library is part of the complete Discovery Channel/Films for the Humanities & Sciences Science Video Library. © 2003