



Instructor's Guide

Electricity: A 3-D Animated Demonstration ELECTRIC GENERATORS

Introduction

This instructor's guide provides information to help you get the most out of *Electric Generators*, 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*.

Electric Generators explores how electricity is generated. The contents of the guide will allow you to prepare your students before using the program and to present follow-up activities to reinforce the program's key learning points.

Learning Objectives

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

- Describe and demonstrate how magnetism induces electricity
- Explain the left-hand rule
- Demonstrate how energy moves a coil inside the magnet of a generator
- Construct a simple generator and explain the principles underlying its operation

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

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 knowledge
- 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 looks at physics principles behind AC and DC generators. The relationship between a changing magnetic field and the induction of electric current is examined. A hand rule is introduced to predict the generator effect in a linear length of conductor exposed to a changing magnetic field. The behavior of a rotating coil in a magnetic field leads to the practical construction of an AC motor. Split-ring commutator generators are introduced, as well as the more common alternator as a means of generating DC electricity.

Main Topics

Topic 1: Generating Electricity

The program's introduction highlights the discovery of how electricity is generated, emphasizing the role of English scientist Michael Faraday.

Topic 2: Inductors

Students learn how magnetism induces electricity.

Topic 3: Generator Left-Hand Rule

This segment explains the "left-hand rule," which helps to identify the direction of magnetic fields that an electric current generates.

Topic 4: Generator Electromotive Rule

In this section, students discover electromotive force — or the "electric potential" that allows the generator effect to occur in the absence of a complete (or actual) circuit.

Topic 5: AC Generators

This segment describes the physics principles that allow for the creation of an AC, or alternating current, generator.

Topic 6: DC Generators

In this final section, students learn how DC, or direct current, generators are created.

Fast Facts

- Danish scientist Hans Christian Oersted discovered that a steady electric current generates a magnetic force.
- A changing magnetic field induces an electric current.
- Michael Faraday accidentally discovered how magnetism induces electricity: the “generator effect” is the term that describes this discovery.
- The “left-hand rule” reminds us of the orientation of magnetic fields an electric current generates.
- A complete circuit is not necessary for the generator effect to happen.
- Alternating current has a pattern of a negative to positive charge.
- AC generators can be modified to provide a source of DC electricity.
- Ohm’s Law is used to calculate the electric current flowing through a circuit.
- The discovery of the battery allowed chemical energy to be converted to an electric current supply.
- By the early 20th century, vast supplies of electricity were generated by induction, thus greatly influencing modern civilization.

Vocabulary Terms

AC generator: Device that produces alternating current; an alternator.

alternator: A generator producing alternating current by the rotation of its rotor, and which is powered by a primary mover.

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.

coil: The loop of conducting wire wrapped around the armature. Each additional armature coil is on a different axis, to produce smoother output voltage.

commutator: The rotating switch attached to the brushes of a DC generator. The commutator maintains DC when the rotation of the armature switches the polarity of the conductor.

DC generator: Device that produces direct current.

dynamic energy: Energy generated by a specific physical force. For example, static electric fields in generators do no work until mechanical (kinetic) energy is applied. The system then becomes dynamic. Generation of useable electricity by physical rotation of the rotor, or armature in a generator, is a producer of dynamically induced power.

electric current: A flow of electrons in an electrical conductor. The strength or rate of movement of the electricity is measured in amperes.

electromagnet: A magnet consisting essentially of a coil of insulated wire wrapped around a soft iron core that is magnetized only when current is flowing through the wire.

electromagnetic field (EMF): The electrical and magnetic fields created by the presence or flow of electricity in an electrical conductor or electricity-consuming appliance or motor.

electromagnetic induction: The use of magnetism to produce electricity.

electromotive force (emf): Electrical pressure. It is the force that pushes electrons through a conductor, measured in volts.

ferromagnetic: The ability to become highly magnetic and have the ability to retain a permanent magnetic moment.

galvanometer: An instrument used to detect, measure, and determine the direction of small electric currents by means of mechanical effects produced by a current-carrying coil in a magnetic field.

generator: A device that converts mechanical energy into electrical energy by magnetic induction.

helix: A coiled structure.

hydroelectric: Electricity produced by turbines that are turned by water flow.

induction: The production of an electric field by a changing magnetic field, or vice versa.

left-hand rule: If fingers of the left hand are placed around a wire so that the thumb points in the direction of electron flow, the fingers will be pointing in the direction of the magnetic field being produced by the conductor.

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

ohm: The metric unit of electrical resistance.

rectifier: An electrical device for converting alternating current to direct current.

sine wave: The most common type of AC waveform. A sine wave consists of 360 degrees and is produced by rotating machines.

slip-ring: A conductive device attached to the end of a generator rotor that conducts current to the brushes.

split-ring: A conductive device that spins rapidly with the armature of a DC motor or generator while in contact with the fixed brushes.

terminal: A connecting point in a circuit where a wire is attached to create an electrical connection.

velocity: A vector measurement of the rate and direction of motion or, in other terms, the rate and direction of the change in the position of an object.

volt: A unit of electromotive force or potential difference.

Pre-Program Discussion Questions

1. What do you think generates electricity?
2. How do magnets figure into electricity?
3. What do you think "electromagnetic induction" means?
4. What is an AC generator? What is a DC generator?
5. For what are AC and DC generators used?

Post-Program Discussion Questions

1. Describe the contribution Michael Faraday's discovery made to modern civilization.
2. What role does the left-hand rule play in electric generation? Explain when and how you might use this rule.
3. What are the primary differences between AC and DC generators? What is significant about these differences?
4. What is the relationship between a conductor, a circuit, a magnetic field, and the generator effect?
5. What is the significance of Ohm's Law with regard to electromotive force?

Individual Student Projects

(Note: Students should maintain journals that document experiment processes and findings.)

The “Shakerator”

Now it's time for students to have some fun experimenting!

Materials

- A roll of 30-gauge varnish insulated magnet wire
- Four powerful bar magnets, about 1 x 2 x 0.5 inches
- A sensitive meter to measure voltage in the range of 0-10 volts (a digital readout is best)
- Several Light-Emitting Diodes (LED), operating in the 1.5 volt range
- Two large corks to cap off the coil ends
- A not-quite-one-inch diameter powerful disk magnet; it should fit loosely in the coil tube
- Another spool of 30-gauge magnet wire

Preparation

Wind a coil of 1,000 turns of 30-gauge insulated magnet wire on a one-inch diameter and five-inch long plastic tube, which is open on both ends. Be sure to do the following before winding: leave about 12 inches of wire free before starting the coil. This is the first of two leads. Also, tape a circle of stiff poster board on each end of the coil tube to hold the wire in place. (The tube and flanges will look like a bobbin.) Wind the coil in layers (neatness is not essential). After finishing the coil, place some strips of transparent tape over the turns to prevent unraveling. Allow 12 inches of wire at the end of the wrapped coil as the second lead. Scrape both leads bright and clean and splice or solder each end to the LED.

Test procedure

Securely cork one end of the coil. Drop the disk magnet into the tube. Cork the open end. Grasp the coil with a thumb on the cork to prevent the disk from popping out, and shake. The LED will light up in response to the induced current generated by the up-and-down motion of the loose magnet in the tube — and thus the amazing “Shakerator.”

Energize the LED...Differently

Students expand on “The Shakerator” in this experiment, using the same materials.

Remove the corks and the magnetic disk. Add a hand drill and a magnet with a mounting screw to provide another means of generating electricity, using the coil from the “Shakerator” experiment. It may be necessary to fill the space inside the coil with an iron tube to concentrate the magnetic field. Now, energize the LED.

How Fun It Is!

Students have an opportunity to see how much fun it can be to learn about electric induction and generators. First, have them read about the interactive instructional methods of M.I.T. physics professor Walter H. G. Lewin:

New York Times: "At 71, Physics Professor Is a Web Star"
<http://www.nytimes.com/2007/12/19/education/19physics.htm>

Then have students watch some of the professor's lectures on topics highlighted in this guide. Students first log on to <http://ocw.mit.edu/OcwWeb/hs/video/n>, and then scroll down to the lectures noted below:

Demonstration: Electromagnetic Induction (8.02, Spring 2002)

or

Demonstration: Faraday's Law (8.02, Spring 2002)

Click on either title to launch the video player, and then click on the following within the RealPlayer window:

- Faraday's Law
- Using Faraday's Law
- Demonstration: Faraday's Law

Also, have students scroll down to:

Demonstration: Electric Generators (8.02, Spring 2002)

Click on the title to launch the video player, and then click on the following within the RealPlayer window:

- Electric Generators
- Demonstrating Electric Generators
- Conducting Coil Moving into a Magnetic Field

Students then outline a lecture they would present on electric generation, perhaps building on the experiments presented in this guide's Group Activities and Individual Student Project sections. In the outline, students spell out the interactive methods they would employ to engage their audience.

Group Activities

(Note: Students should maintain journals that document experiment processes and findings. Also, the second experiment builds from the first one. If the second is to be a stand-alone, use the materials noted in the first. The third activity uses the same materials.)

Making a Generator

Students can construct generators in small groups. Log on to the following Web sites to select one or more generator-making activities or lesson plans.

- Metacafe: Simple Electric Generator: www.metacafe.com/watch/912594/simple_electric_generator
- Pulse: Home-made Generator:
http://pulse.pharmacy.arizona.edu/12th_grade/powerful_explor/physics/homemade_generator.html
- Science Project: Electric Generator: www.scienceproject.com/A/projects/KITWG/index.asp

Testing Faraday's Theory

Michael Faraday believed and proved (in 1831) that a changing magnetic field is necessary to induce a current in a nearby circuit. In order for this to occur, something has to physically move to get electrons in a conductor to flow. This experiment demonstrates to students how such electric generation occurs.

Materials

- A roll of 30-gauge varnish insulated magnet wire
- Four powerful bar magnets, about 1 x 2 x 0.5 inches
- A sensitive meter to measure voltage in the range of 0-10 volts (a digital readout is best)
- Several Light-Emitting Diodes (LED), operating in the 1.5 volt range

Preparation

- Wrap about 20 turns of wire around a form of an inch in diameter. Leave about five inches of wire at the start and end of the winding. Remove the coil from the form and use masking tape strips to prevent unraveling.
- Using a knife blade, strip away an inch of insulation (usually a colored varnish) from each end of the coil pigtailed.
- Connect these copper ends to the voltmeter leads and adjust the voltmeter to the lowest DC voltage range.

Test Procedure

- Place the coil, now connected to the voltmeter, flat against the table surface. It can be taped in place.
- Pick up a bar magnet and wave it over and near the coil. (The magnet and coil should be as close to each other as possible, but not touching.) Observe the meter readout. Small but perceptible voltages, maybe as high as .08 volts, should appear. The numbers will vary as the magnet moves randomly over the coil.

- With the magnet resting on the table, wave the coil over it. What happens? (Voltage is induced in the coil.) It doesn't seem to matter which element moves for induction of current.
- Next, lay the magnet near the coil and check the meter. Since there is no motion, no current flows and no voltages register.

Electric Generation...More Of It

Students build on the first experiment (using the same materials) to further discover how electricity is generated.

Preparation

Raise the 20-turn coil on a stand about a foot above the tabletop. This allows enough space above and below for the bar magnet to move freely through the coil. Join several bar magnets end to end in order to provide a better handhold on the magnets.

Test Procedure

Observing the meter, move one end of the magnet through the center of the coil. The voltage should peak at either a plus or minus value. Then, when the magnet is centered in the coil, the voltage will return to zero on its way to a peak value of the opposite polarity as the magnet emerges out the bottom of the coil. Try doing this at different speeds and note the effect on peak voltage. Allow a magnet to freefall through the coil and note the behavior on the voltmeter.

Observe the same effect by inserting the magnet into the coil halfway and then withdrawing it in the opposite direction.

What occurred here, in a humble way, is generation of AC electricity by applying mechanical hand motion to move a rotor, the magnets, through a fixed coil, the stator. It is a generator of electricity in the truest sense. It is important to remember that the above is possible only because of electromagnetic induction.

Bonus Experiment

Preparation

- Wind a coil of 500 turns of 30-gauge magnet wire on a 1-inch diameter and 5-inch long plastic tube.
- Extend the length of the magnet by connecting all four magnets.
- Remove the insulation from the coil wire ends as before.
- Replace the voltmeter with an LED that operates in the 1.5 volt range.

Test Procedure

Insert the end of the magnet assembly into the coil. The LED should light up while the magnets are in motion. Try varying the speed of insertion. The increase in the number of turns results in the generation of enough voltage to operate a device — in this case, an LED.

Internet Activities

All About Faraday

Students further explore Michael Faraday's work with electricity to create an annotated timeline of his experiments and discoveries. Sites to jumpstart research include:

- <http://books.google.com> (search on *Experimental Researches in Electricity* to obtain a PDF of this excellent primary source document)
- <http://chem.ch.huji.ac.il/history/faraday.htm> (The Institute of Chemistry — Hebrew University of Jerusalem's Faraday page)
- <http://www.rigb.org/heritage/faradaypage.jsp> (The Royal Institution of Great Britain Faraday page)

Surveying AC-DC Generator Web Sites

Students locate and compare and contrast a variety of Web sites centered on electric generators. After logging on and using the sites' interactive tools, students rate them for things such as ease of use, quality of information provided, how easy content is to grasp, etc. Students create a site review for use by appropriate teachers and students. (Note: Some of these sites are included in this guide's *Additional Resources* section.)

Electric Generators: How They Work

Students log on to "How Electricity Works: Generators" at <http://science.howstuffworks.com/electricity2.htm>. Using this article as a model, students write a similar online article to describe how an AC or DC generator works and how a hydroelectric generator functions. Students may pitch the article to "How Stuff Works" editorial staff.

Assessment Questions

- 1: Which statement is *not* true about the English scientist Michael Faraday?
- a) He found that a constant magnetic field generates an electric current.
 - b) He found that a constant magnetic field does not generate an electric current.
 - c) He found how magnetism induces electricity.
- 2: What is electromagnetic induction?
- 3: The _____ is used to determine the flow of an electric current the generator effect induces.
- a) galvanometer
 - b) left-hand rule
 - c) movement of a conducting wire
- 4: The potential in a disconnected circuit is known as _____.
- a) resistance
 - b) electromagnetism
 - c) electromotive force
- 5: How does moving a magnet past a coil of wire affect the current passing through that coil?
- 6: Ohm's Law is used to calculate _____.
- a) electric current flowing through a circuit
 - b) electromotive force
 - c) a generator's electric potential
- 7: In the equation $\text{emf} = vB \perp L$, what do v , B , and L represent?
- 8: What element does a generator share with a motor?
- a) rotating coil
 - b) magnetic field
 - c) a & b
- 9: What is significant about the 90-degree angle in the coil rotation of a generator?
- 10: Alternating current has a pattern of _____.

Assessment Questions Answer Key

1: Which statement is *not* true about the English scientist Michael Faraday?

- a) He found that a constant magnetic field generates an electric current.
- b) He found that a constant magnetic field does not generate an electric current.
- c) He found how magnetism induces electricity.

A: a

Feedback: In 1831, Faraday tested this theory: that a steady force from a magnet might create an electric current. In testing his theory, he created an electromagnet that he would power up. To induce electricity, he established a separate circuit, winding another wire around the core, and attached it to a galvanometer, which would detect the presence of a current. When he powered up the electromagnet, the galvanometer briefly registered a current. This occurred again when the electromagnet was turned off. What Faraday learned was that a changing magnetic field generates an electric current. From this finding, he accidentally discovered that magnetism induces electricity.

2: What is electromagnetic induction?

A: It is a way in which mechanical energy spent to move a magnet can be converted into electric energy moving through a wire.

Feedback: Faraday's work led to this understanding. He determined that as a magnetic field moves in relation to the conductor, electricity is generated.

3: The _____ is used to determine the flow of an electric current the generator effect induces.

- a) galvanometer
- b) left-hand rule
- c) movement of a conducting wire

A: b

Feedback: For generators, the left hand rule explains the nature of current flow in a conducting coil. On one side of the coil, the fingers are aligned with the magnetic field, and the thumb indicates the direction in which this side of the wire moves as the coil twists. The palm indicates the direction of current flow through the wire.

4: The potential in a disconnected circuit is known as _____.

- a) resistance
- b) electromagnetism
- c) electromotive force

A: c

Feedback: Electromotive force describes the theoretical capability of a generator to work, without reference to the actual circuit in which resistance will inevitably reduce the current flow.

5: How does moving a magnet past a coil of wire affect the current passing through that coil?

A: An electric current moves in the same direction as the conductor, in this case the magnet.

Feedback: Faraday determined that it is only necessary to move a magnetic field past a conductor, or vice versa, to generate a flow of electric current in the conductor.

6: Ohm's Law is used to calculate _____.

- a) electric current flowing through a circuit
- b) electromotive force
- c) a generator's electric potential

A: a

Feedback: Using Ohm's Law with an electromotive force in volts, and the resistance in ohms, actual current flowing through the circuit can be easily calculated.

7: In the equation $emf = vB\perp L$, what do v , B , and L represent?

A: v = velocity of moving conductor; B = strength of magnetic field; L = length of conductor moving through the field

Feedback: Electromotive force varies directly as the velocity of the moving conductor, directly as the strength of the magnetic field, and directly as the length of the conductor of the moving field.

8: What element does a generator share with a motor?

- a) rotating coil
- b) magnetic field
- c) a & b

A: c

Feedback: Like a motor, a generator employs both a rotating coil and a fixed magnetic field. And like the rotating coil of an electric motor, the rotating coil of a generator is made more powerful with more turns of the coil within the magnetic field.

9: What is significant about the 90-degree angle in the coil rotation of a generator?

A: It is at the 90-degree angle when the emf drops to zero.

Feedback: At the 90-degree angle to the plane of magnets, the emf drops to zero and current flow momentarily stops. As the rotation continues, the emf begins to build again, with the current moving in the opposite direction. It reaches its greatest flow in the opposite direction in the plane of the magnets, then the current diminishes as it approaches the opposite-right angle to this plane, where it falls once again to zero, then begins the cycle over again.

10: Alternating current has a pattern of _____.

A: negative to positive charge

Feedback: See Feedback to 9 above. Over time, the pattern of changing current is a cycling wave. Alternating current has the pattern of negative to positive charge: it's what is actually being produced. A generator connected through a pair of slip-ring commutators, mechanical power to rotate the coil, is an alternating current, or AC generator.

Additional Resources

BOOKS

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

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

Basic Electricity: Reprint of the Bureau of Naval Personnel Training Manual, by Staff of the Bureau of Naval Personnel. Barnes & Noble Books, 2004. ISBN: 9780760752388

Electricity and Magnetism: Stop Faking It! Finally Understanding Science So You Can Teach It, by William C. Robertson, Ph.D. National Science Teachers Association, 2004. ISBN: 0873552369

Principles of Electricity and Magnetism, by Saunak Palit. Alpha Science Int'l Ltd, 2005.
ISBN: 1842652052

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

WEB SITES

All About Circuits

www.allaboutcircuits.com/vol_1/chpt_2/4.html

BrainPOP

www.brainpop.com

comPADRE: Digital Resources for Physics & Astronomy Education

www.compadre.org

Computational Science Education Reference Desk: Discovering Ohm's Law

www.shodor.org/refdesk/Resources/Activities/OhmsLaw

Energy Information Administration, U.S. Department of Energy

Energy Kid's Page

www.eia.doe.gov/kids/energyfacts/sources/electricity.html#Generation

Explore Learning

www.explorelearning.com (search on *Electricity and Magnetism*)

Foundation for Water & Energy Education: Walk through a hydroelectric project

www.fwee.org/walktour

HyperPhysics

<http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html>

IEEE

www.ieee.org

NDT Resource Center: Introduction to Electricity

www.ndt-ed.org/EducationResources/HighSchool/Electricity/electricityintro.htm

National Science Teachers Association

www.nsta.org

PhysicsCentral

www.hinsdale86.org/staff/jliaw

The Physics Classroom

www.physicsclassroom.com

The Physics Front.org

www.thephysicsfront.org

PhysicsLAB Online

<http://dev.physicslab.org>

Rutgers University: Physics Teaching Technology Resource

<http://paer.rutgers.edu/pt3/index.php>

MIT OpenCourseWare: Highlights for High School

<http://ocw.mit.edu/OcwWeb/hs/home/home/>

Molecular Expressions: AC Generator Action

<http://micro.magnet.fsu.edu/electromag/java/generator/ac.html>

Molecular Expressions: DC Generator Action

<http://micro.magnet.fsu.edu/electromag/java/generator/dc.html>

Molecular Expressions: Faraday's Magnetic Field Induction Experiment

<http://micro.magnet.fsu.edu/electromag/java/faraday2>

Molecular Expressions: Generators and Motors
<http://micro.magnet.fsu.edu/electromag/electricity/generators/index.html>

NDT Resource Center: Electricity
www.ndt-ed.org/EducationResources/HighSchool/Electricity/hs_elec_index.htm

PBS: The American Experience — AC/DC: What's the Difference?
www.pbs.org/wgbh/amex/edison/sfeature/acdc.html

PBS: The American Experience — AC-DC: Inside the AC Generator
www.pbs.org/wgbh/amex/edison/sfeature/acdc_insideacgenerator.html

Science Joy Wagon: The Physics Zone: Electrical Generator — AC or DC
www.sciencejoywagon.com/physicszone/otherpub/wfendt/generatorengl.htm

Wisconsin Valley Improvement Company: How an Electric Generator Works
www.wvic.com/how-gen-works.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

Electromagnetism (6-part series)

- DVD/VHS #3555
- Preview clip online
- Close captioned
- Correlates to educational standards
- Includes viewable/printable instructor's guides

This series of computer-animated programs explores this mysterious force, from early observation to modern theories about the role of Earth's magnetic field. The series includes *Earth's Magnetic Field* • *Magnetism and Electron Flow* • *Domain Theory* • *The Motor Principle* • *Electromagnetic Induction* • *Life in the Field*. (10 minutes each)

Einstein Made Relatively Easy

- DVD #35602
- [Preview clip online](#)
- **Correlates to educational standards**

Introducing EinSteinchen, an animated techno-Einstein who has a genius for explaining physics. In section one of this DVD, this likable know-it-all elucidates 12 essential topics in 90-second segments that are perfect for launching lectures or illustrating concepts. Section two departs from EinSteinchen's virtual world to show 12 cutting-edge applications or studies of Einsteinian physics in high-level mini-documentaries of two to five minutes in length. A Deutsche Welle Production. (60 minutes) © 2006

Section one's animated segments include the following: *Absolute and Relative* • $E=mc^2$ • *The Discovery of Slowness* • *As Fast as Light* • *Glowing Atoms—Stimulated Emissions* • *The Super-molecule—Bose-Einstein Condensation* • *The Spooky Long Distance Effect* • *Bent Space* • *Dancing Particles* • *Electricity from Light* • *The Invisible Force* • *Wormholes*.

Section two's mini-documentaries include the following: *Nuclear Medicine—A Formula and Its Results* • *Satellite Navigation* • *The Speed of Light, Part 1—Light Researchers* • *The Speed of Light, Part 2—Radar Satellite* • *The World's Fastest Flash* • *Juggling Ultra-cold Atoms* • *Cloned Atoms through Teleportation* • *Cosmic Telescopes* • *Racing Down Einstein's Paths* • *Organic Solar Cells* • *Time Travel through Wormholes—Nothing More Than a Dream?* • *The Search for a Theory of Everything*.

Electricity and Electronics

- DVD/ VHS #34798
- [Preview clip online](#)
- **Close captioned**
- **Correlates to educational standards**
- **Includes viewable/printable instructor's guides.**

This ten-part series provides a comprehensive video guide to the study of electronics, ranging from the fundamental laws and principles of electricity at the atomic level to troubleshooting and repair of electronic components. Lively computer animation and hands-on demonstrations make these videos an ideal resource for the classroom. The series includes the following titles: *Electrical Principles* • *Electrical 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 Circuit Repair*. A Shopware Production. (18-24 minutes each) © 2006

Electric Power on the Move

- **DVD #34288**
- **Preview clip online**
- **Correlates to national science educational standards**
- **Includes viewable/printable instructor's guide**

This *Science Screen Report* examines the production, transportation, and consumption of electricity. Using the Hoover Dam as an example of efficient hydroelectric power generation, the program illustrates how transformers raise or lower voltage to manageable levels and how electricity is specifically channeled to illuminate buildings, power devices, and propel vehicles. Vital electrical concepts are discussed, including the difference between alternating and direct current, the advantages of neon over filament bulbs, and the definitions and significance of ohms, volts, and amperes. Produced in association with the Accreditation Board for Engineering and Technology and the Junior Engineering Technical Society. (18 minutes) © 2004

Physical Processes

- **CD-ROM #8116 (Windows/Macintosh)**
- **Preview clip online**

Pictures, diagrams, text, sound, and video help students understand electricity, electromagnetism, energy, forces and motion, and sound and light in this completely interactive CD-ROM.

- *Forces and Motion* includes information on forces of attraction and repulsion, gravity, friction, springs and elastic, balanced and unbalanced forces, speed, distance and time, moments and pivots, pressure, and measuring forces.
- *Light and Sound* answers questions such as: What are waves? What makes sounds? Topics include pitch and frequency; loudness and amplitude; sound traveling in different materials; hearing; effects of properties of light; how light is reflected; colors in white light; effects of color filters; and modern applications of light.
- *The Earth and Beyond* includes information on apparent movement of the sun and stars; night and day; relative positions and motion of the planets; eclipses; the earth as seen from space; comets and asteroids; and the life cycle of stars.
- *Energy Source and Energy Transfer* includes information on the variety of energy sources—coal, oil, natural gas, water, solar, nuclear, wind, wave, tidal, geothermal, and batteries. Generation of electricity is discussed, along with finite and renewable sources, energy transfer and conservation, and the impact of production on the environment.

Physics in Action

- **DVD/ VHS #1916**
- **Preview clip online**
- **Correlates to educational standards**

This 10-part series comprises an anthology of demonstrations and quantitative experiments taught in introductory physical science. The experiments selected are ones that are difficult or impossible to perform in most school laboratories. The quantitative experiments are designed to permit students to record data from the screen and perform their own calculations. The programs also contain illustra-

tions of physics principles at work in industry, business, and at home. The series includes the following titles: *Electrostatics* • *Electrostatics 2* • *The Generation of Electricity* • *Commercial Generation and Transmission of Electricity* • *Electricity in the Home* • *Radioactivity* • *The Thermal Expansion of Metals* • *The Electromagnetic Spectrum* • *The Laws of Motion* • *The Laws of Motion Applied*. (20 minutes each)

Electrons at Play: A Century of Electrifying Discoveries

- **DVD/ VHS #11324**
- **Preview clip online**
- **Correlates to educational standards**

This lively program presents the 1998 Faraday Lecture, which explains how the discovery of the electron by J. J. Thomson profoundly impacted both everyday life and scientific innovation. Combining stimulating on-stage experiments, computer graphics, interviews, and even a visit to CERN, the European Laboratory for Particle Physics, the program illustrates the principles of electrostatics and electromagnetism, examines the workings of the cathode ray tube and flat-screen TV, and inquires into the origin of the universe. A Wimshurst machine, a Tesla coil, a plasma globe, an electron microscope, and a particle accelerator are demonstrated. (55 minutes) © 1998