Elements of Physics: Energy, Work, and Power
Teacher's Guide

Grade Level: 9–12	**Curriculum Focus:** Physical Science	**Lesson Duration:** Three class periods

Program Description

Much of our success as an industrialized society stems from our ability to harness energy. Explore the many different forms energy can take—sound, heat, light, chemical, and nuclear. Students learn how energy can be converted from one form to another. They also learn that modern physicists, unlike their predecessors, believe that energy and matter are fundamentally linked.

Onscreen Questions

- What are some different forms of energy?
- How are energy and matter related?
- How does an engine transform energy?
- Why should cars use energy efficiently?

Lesson Plan

Student Objectives

- Understand the difference between potential and kinetic energy.
- Describe what causes variations in the amount of potential energy an object has.
- Apply knowledge of potential and kinetic energy to a real-world situation.

Materials

- *Elements of Physics: Energy, Work, and Power* video
- Computers with Internet access (for this lesson, every two students need a computer)
- Paper and pencils

Procedures

1. Ask students to write down on a sheet of paper what they think the following terms mean: potential energy and kinetic energy. Then have students put the sheets away.

2. Tell students that during the lesson, they will work with a partner to design an online roller coaster. To design a safe, fun ride, they need to know some basic facts about potential and kinetic energy. Have students watch the segment "The Work of Energy," part of the program *Elements of Physics: Energy, Work, and Power* for background information.

3. Have a brief discussion about potential and kinetic energy. Develop a class definition and write it on the chalkboard. Sample definitions are listed below.
   - Potential energy: The energy of a an object at rest
   - Kinetic energy: The energy of objects in motion

4. Divide students into pairs and have each pair sit in front of a computer. Direct students to the following Web site: http://www.learner.org/exhibits/parkphysics/coaster/. Tell students to follow the prompts to design a safe and exciting roller coaster ride. Ask them to make decisions about the following:
   - The height of the first hill
   - The shape of the first hill
   - The exit path
   - The height of the second hill
   - The loop

5. If students have trouble making decisions about each of these items, help them get started by posing the following questions:

   Q: The more energy a roller coaster has at the beginning of the ride, the more successful the ride. That means it needs to begin with a lot of potential energy. What factor do you think affects the amount of potential energy the roller coaster will have?
   A: Height affects the amount of potential energy the roller coaster will have. So the higher the hill at the beginning of the ride, the more potential energy the roller coaster will have.

   Q: What do you think is the safest way to "come down" from the first hill?
   A: By following a slightly curved path , the roller coaster will move gently down the hill.

Q: How do you think the roller coaster should exit from the first hill?
A: Just as a roller coaster needs a gentle descent, it also needs a gentle exit. Because of the kinetic energy of the roller coaster, if it exited too quickly, it could run off the track.

Q: What do you think the height of the second hill should be?
A: To build up momentum for the rest of the ride, the hill should be fairly high. The greater the height, the more potential energy builds up.

Q: What shape do you think the loop should be?
A: As long as enough potential energy has built up so that the roller coaster has enough energy to finish the ride, an elliptical loop is the safest option.

6. Give students time in class to build their online roller coaster. Ask them to write down their choices on a sheet of paper and draw a picture of each element of their roller coasters.

7. During the next class period, go over students' roller coaster designs. Have each pair present their ideas and share their drawings. Gain class consensus on the most exciting and safest roller coaster design.

8. Conclude the lesson by having each pair check their designs against the safety inspection presented at http://www.learner.org/exhibits/parkphysics/coaster/. If students made mistakes, make sure they understand what they did wrong and how they can correct their mistakes. Also, make sure students have a clear understanding of the relationship between roller coaster rides and potential and kinetic energy.

Assessment

Use the following three-point rubric to evaluate students' work during this lesson.

- **3 points:** Students showed a clear understanding of the difference between potential and kinetic energy; could describe accurately what causes variations in the amount of potential energy an object has; and could accurately apply their knowledge of potential and kinetic energy to a real-world situation.
- **2 points:** Students showed a satisfactory understanding of the difference between potential and kinetic energy; could describe somewhat accurately what causes variations in the amount of potential energy an object has; and could apply somewhat accurately their knowledge of potential and kinetic energy to a real-world situation.
- **1 point:** Students showed a weak understanding of the difference between potential and kinetic energy; could not describe what causes variations in the amount of potential energy an object has; and had difficulty applying their knowledge of potential and kinetic energy to a real-world situation.

Vocabulary

energy
Definition: Usable power
Context: Heat and sound are two different kinds of energy.

force
Definition: A push or pull acting on an object
Context: When you kick a soccer ball, your foot applies a force to the ball, causing it to move forward.

kinetic energy
Definition: The energy of objects in motion
Context: Cars zooming down a highway have kinetic energy because they are traveling over a distance.

momentum
Definition: The amount or quantity of motion an object has
Context: Because roller coaster cars have a lot of mass, they gain momentum as they go faster.

potential energy
Definition: The energy of an object at rest
Context: The higher the first hill the roller coaster ascends, the more potential energy will build, and the greater the amount of kinetic energy the roller coaster will have.

Academic Standards

National Academy of Sciences
The National Science Education Standards provide guidelines for teaching science as well as a coherent vision of what it means to be scientifically literate for students in grades K–12. To view the standards, visit http://books.nap.edu/html/nses/html/overview.html#content.

This lesson plan addresses the following national standards:

- Physical Science: Motion and forces
- Science and Technology: Abilities of technological design; Understanding about science and technology

Mid-continent Research for Education and Learning (McREL)

McREL's Content Knowledge: A Compendium of Standards and Benchmarks for K–12 Education addresses 14 content areas. To view the standards and benchmarks, visit http://www.mcrel.org/compendium/browse.asp.

This lesson plan addresses the following national standards:

- Science: Physical Sciences—Understands forces and motion
- Technology—Understands the nature and uses of different forms of technology
- Language Arts: Viewing—Uses viewing skills and strategies to understand and interpret visual media; Writing: Uses the general skills and strategies of the writing process, Gathers and uses information for research purposes; Reading: Uses reading skills and strategies to understand and interpret a variety of informational texts

The National Council for the Social Studies (NCSS)

NCSS has developed national guidelines for teaching social studies. To become a member of NCSS, or to view the standards online, go to http://www.socialstudies.org/standards/strands/.

This lesson plan addresses the following thematic standards:

- Time, Continuity, and Change
- Individuals, Groups, and Institutions

DVD Content

This program is available in an interactive DVD format. The following information and activities are specific to the DVD version.

How to Use the DVD

The DVD starting screen has the following options:

Play Video—This plays the video from start to finish. There are no programmed stops, except by using a remote control. With a computer, depending on the particular software player, a pause button is included with the other video controls.

Video Index—Here the video is divided into sections indicated by video thumbnail icons; brief descriptions are noted for each one. Watching all parts in sequence is similar to watching the video from start to finish. To play a particular segment, press Enter on the remote for TV playback; on a computer, click once to highlight a thumbnail and read the accompanying text description, and click again to start the video.

Curriculum Units—These are specially edited video segments pulled from different sections of the video (see below). These nonlinear segments align with key ideas in the unit of instruction. They include onscreen pre- and post-viewing questions, reproduced below in this Teacher's Guide. Total running times for these segments are noted. To play a particular segment, press Enter on the TV remote or click once on the Curriculum Unit title on a computer.

Standards Link—Selecting this option displays a single screen that lists the national academic standards the video addresses.

Teacher Resources—This screen gives the technical support number and Web site address.

Video Index

I. The Work of Energy

Discover the relationship between work and energy. Learn the difference between potential and kinetic energy.

II. Energy Around Us

Examine several forms of kinetic energy, including heat and sound energy. Discover why NASA relies so heavily on solar energy for space vehicles and other objects.

III. Behavior and Laws of Energy

Examine the three laws of thermodynamics. Take a closer look at different types of energy exchanges.

IV. Cars: Energy in Motion

Tour the world of car design to see unique cars of the past and future. Discover how automobile engines convert potential energy to motion.

Curriculum Units

1. Relationship of Work and Energy

Pre-viewing question
Q: How do you use energy?
A: Answers will vary.

Post-viewing question
Q: What is the difference between kinetic and potential energy?
A: Kinetic energy is the energy of objects in motion. Potential energy is the energy of objects at rest. A roller coaster sitting on a track has potential energy. A moving roller coaster has kinetic energy.

2. Forms of Kinetic Energy

Pre-viewing question
Q: What are some forms of kinetic energy?
A: Answers will vary.

Post-viewing question
Q: How does NASA use solar energy?
A: NASA scientists put solar panels on satellites, space telescopes, and unmanned Mars rovers. These vehicles operate on electrical energy and cannot use gasoline or other fuel because it is impossible to refuel on Mars.

3. Electromagnetic Energy

Pre-viewing question
Q: Describe static electricity.
A: Answers will vary.

Post-viewing question
Q: How does static electricity occur?
A: Static electricity is the buildup of a charge on an object, which may result in an electrical discharge. Usually, negatively charged electrons balance positively charged protons, but electrons jumping from atom to atom create an imbalance. Electrical charges build up and concentrate in groups of atoms; a discharge occurs when electrons jump to other atoms to balance their protons.

4. Energy Exchanges

Pre-viewing question
Q: How do you use electricity?
A: Answers will vary.

Post-viewing question
Q: Describe the three laws of thermodynamics.
A: The first law of thermodynamics, often called the law of conservation of energy, states that energy cannot be created or destroyed, so the total amount of energy in the universe remains constant. The second law states that the temperature of a substance eventually reaches a state of equilibrium. For example, when a popsicle melts in hot water, the mixture of the cold popsicle and the hot water evens out when the popsicle melts. This law also predicts that all energy, particularly heat, eventually reaches equilibrium. The third law states that as a substance approaches the temperature of absolute zero, -273ºC or -460ºF, the extraction of energy becomes more difficult because the atoms have almost no movement. However, electrons can pass through some substances at temperatures close to absolute zero with no resistance, making it much easier to transmit electricity.

5. Combustion and Engine Efficiency

Pre-viewing question
Q: What skills are necessary to repair cars and other vehicles?
A: Answers will vary.

Post-viewing question
Q: Why does the two-stroke engine present an environmental problem?
A: There are no valves on top of the two-stroke cycle engine; instead, the piston acts as a valve. As it slides up and down, it opens and closes the exhaust and inlet ports on the side of the cylinder. But at the bottom of the piston stroke, both inlet and exhaust ports are open. As much as 30 percent of the fuel used in a two-stroke can come into the intake and out of the exhaust and never be a part of the combustion process. This gives no fuel economy and very high carbon emissions.

6. Designing a Car

Pre-viewing question
Q: What are some positive features of a car?
A: Answers will vary.

Post-viewing question
Q: What considerations must automobile designers keep in mind?
A: Car designers must consider whether a design is too expensive to produce, if production materials can match their design, if parts can be stacked and shipped easily, if workers can fasten

parts quickly, if designs match safety and government requirements, if the car will be able to withstand rugged conditions, and if the design will attract people enough to make a purchase.

7. A Turning Point in Car Culture

Pre-viewing question
Q: Describe an interesting or unusual car.
A: Answers will vary.

Post-viewing question
Q: Why did American attitudes toward automobiles change at the end of the 1950s?
A: In 1957, Ford Motor Company presented the Edsel, which was a spectacular failure because it was poorly engineered, shoddily built, and had little appeal. Five years later, Ralph Nader wrote *Unsafe at Any Speed*. Combined with congressional investigations into car accidents, Nader's book opened the door to greater federal safety regulations for the auto industry. The OPEC oil crisis further cooled America's love for flashy, unique cars.

8. Concept Cars and Fuel Cells

Pre-viewing question
Q: What might be the best type of car in the future?
A: Answers will vary.

Post-viewing question
Q: What are the pros and cons of using fuel-cell technology in automobiles?
A: When hydrogen is combined with oxygen in a fuel cell, the result is a little water and a lot of energy in the form of electricity. With an efficiency rate of 50 percent, a fuel cell engine is more efficient than an internal combustion engine, which is only 15 percent efficient. But fuel cells are very expensive because the materials needed to make them are expensive. In addition, hydrogen is dangerous because it burns when ignited in open air.