Active Physics® Course Overview

THIRD EDITION

PHYSICS FOR ALL

A Project-Based Inquiry Approach

What Inquiry Should Be

IT's ABOUT TIME®
HERFF JONES EDUCATION DIVISION

Introducing the new Active Physics®.

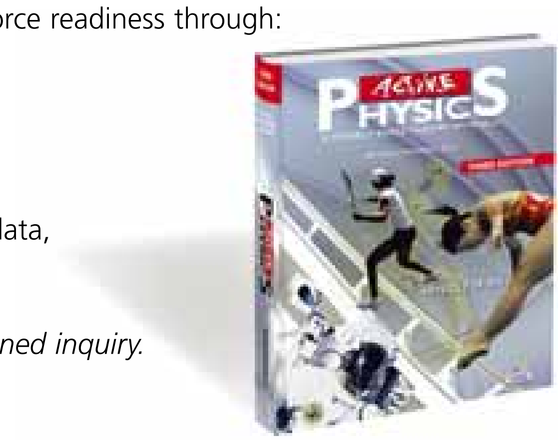
Tough enough for 300 mph wind speeds... Strong enough to hold up a 2 1/2 ton elephant... Bold enough for Arthur Eisenkraft's standards.

When you have been a teacher in the classroom for over 25 years you learn what students can do when you challenge them. More importantly, you begin to understand that how you challenge your students makes a real difference.

Active Physics Third Edition, a core project-based curriculum that has strong content that addresses all state Standards. It also includes *Active Physics Plus* for those students who want a bit more of a stretch than everybody else. You'll be surprised by how many students step up to the challenge. That's why *Active Physics Third Edition,* is ***Physics For All***.

For Students, Active Physics Third Edition:

- engages students through real-world challenges and projects that require physics knowledge coupled with student creativity. Students engage in inquiry from start to finish.
- has students observe and explore before building models and explanations for phenomena. They aren't physics students, they are student physicists.
- prepares students for the 21st century and workforce readiness through:
  sustained **STEM** activities,
  sustained collaboration,
  sustained communicating of plans and ideas,
  sustained development of explanations,
  sustained critical thinking,
  sustained collecting, organizing, and analyzing data,
  sustained observing and interpreting,
  sustained use of evidence to support claims.



The result— lasting knowledge and skills through sustained inquiry.

For Teachers, Active Physics Third Edition:

- values what we, as teachers, value—inquiry-based learning supported by research on how people learn, how students are motivated and how to best assess learning.
- helps us to elicit students' prior understandings and provides a pathway to guide students to higher achievement.
- has everything we need as teachers including: labs as part of the instructional model, physics explanations emerging from the evidence, assessments to find out what students know, differentiated instruction to ensure success for all students. And, it's all in one place so that you never have to search to gather resources.

As you know, these aren't just Arthur Eisenkraft's Standards—they are the Standards that we have all adopted. They are Standards that can provide *Physics For All.*

Chapter 1: Driving the Roads

Chapter Challenge

The challenge for this chapter is to demonstrate your knowledge of the physics of driving by making a presentation to a board of driving instructors. The instructors will evaluate your knowledge in both an oral and written presentation on the physics of braking distances, friction and curves, safe following distances, and yellow-light intersections.

Section Summaries	Physics Principles
Section 1 Reaction Time: Responding to Road Hazards Using various reaction timers, students explore the time it takes them to react to a situation. This section introduces students to the process of first beginning with their own ideas and predictions, then implementing an investigation that results in both qualitative and quantitative data.	**Reaction time**
Section 2 Measurement: Errors, Accuracy, and Precision Students count the number of strides it takes them to cover a selected distance in an area away from traffic. Students measure the length of their stride using a meter stick and calculate the entire distance by multiplying the total number of strides with the length of each stride. The measurements are then compared by each group. By comparing measurements students arrive at an understanding of error and the different kinds of errors present in a measurement.	**Errors in measurement** **Accuracy** **Precision**
Section 3 Average Speed: Following Distance and Models of Motion Strobe or multiple exposure photos of a moving vehicle are used to illustrate speed and acceleration. Students then use a motion detector to measure their walking speed and obtain a computer generated graph of their motion. Information about speed and velocity is then connected to reaction distance with a discussion on tailgating.	**Average speed** **Instantaneous speed** **Velocity** **Reaction distance**
Section 4 Graphing Motion: Distance, Velocity, and Acceleration Students use sloped tracks to investigate the speed and distance an automobile travels before stopping. They then examine data on time and distance required to stop a vehicle moving at various speeds. This is connected to the total time required to react to a hazard, apply force to the brake, and slow the motion of the vehicle to a complete stop.	**Acceleration** **Positive acceleration** **Negative acceleration** **Vector quantity**
Section 5 Negative Acceleration: Braking Your Automobile The students investigate the relationship between an automobile's speed and the distance required to bring it to a stop. Students draw graphs to study the change in velocity with respect to time. The concept of negative acceleration is explored in this context.	**Negative acceleration** **Braking distance**
Section 6 Using Models: Intersections with a Yellow Light Using a spreadsheet model of an intersection, students explore how reaction time, speed, and stopping distance affect what they should do at a yellow light. This also introduces them to how transportation engineers use a computer simulation to model various factors affecting decisions about speed limits and traffic-light cycles. Students now have the opportunity to apply their understanding of reaction time, distance vs. velocity, and braking distance to identify the STOP, GO, and Dilemma Zones at intersections when they see a yellow light.	**Speed** **Negative acceleration** **Distance vs. time relationships**
Section 7 Centripetal Force: Driving on Curves Students' perceptions and prior learning about the force needed to change the direction of a moving object are challenged in this section. After performing investigations, they reflect on the discrepancy between their perceptions and observed results. Students then read for more information on how forces change the direction of motion.	**Force** **Centripetal force** **Centripetal acceleration**

Chapter 2: Physics in Action

Chapter Challenge

The challenge for this section is to develop a 2–3 minute voice-over for a sports clip explaining the physics involved in the sport. The voice-over should be entertaining, as well as explain how a number of physics principles determine what is occurring during the sport. In addition, a written script will be submitted.

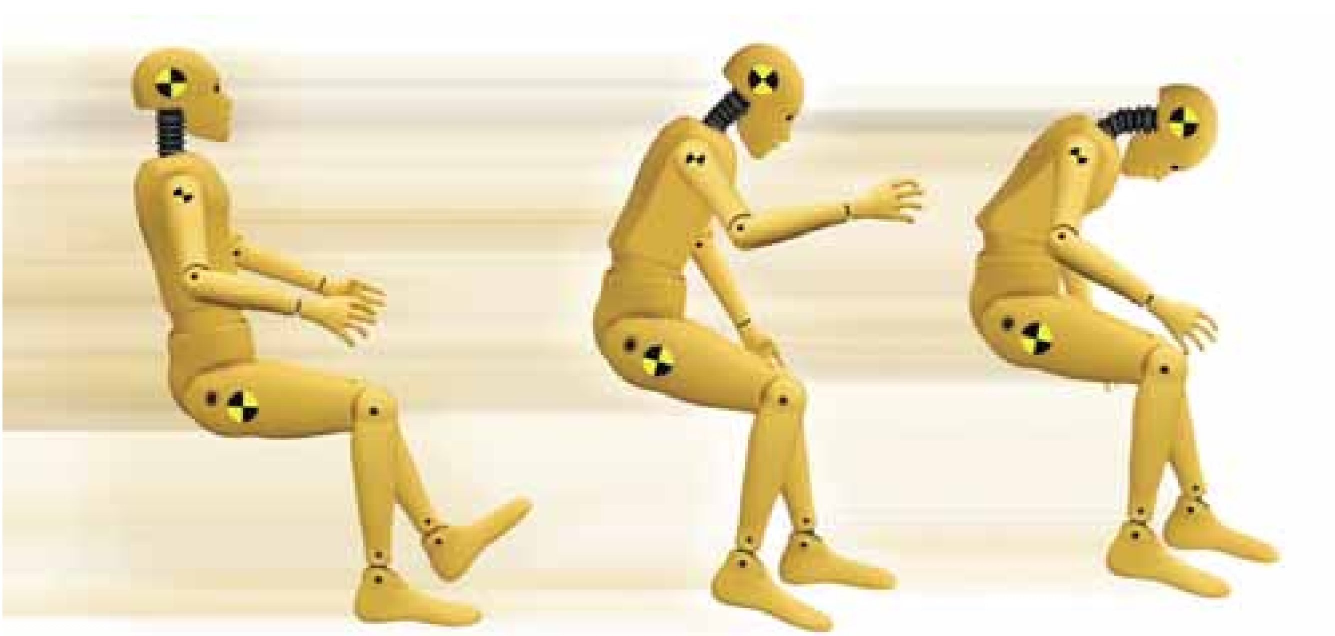
Section Summaries	Physics Principles
Section 1 Newton's First Law: A Running Start Students release a ball to roll down and then up the sides of a track. They first record its starting height and then the recovered height. From this, they are introduced to the concept of inertia.	**Inertia and mass, Newton's first law of motion, Force, Velocity and speed, Acceleration, Frames of reference**
Section 2 Constant Speed and Acceleration: Measuring Motion A timer and paper tape are used to record the motion of various objects. Distance, time, instantaneous and average velocities, and accelerations are calculated from the data.	**Instantaneous speed Average speed Positive acceleration Negative acceleration**
Section 3 Newton's Second Law: Push or Pull Students calibrate and use a simple force meter to explore the variables involved in the acceleration of an object. They then connect their observations and data to a study of Newton's second law of motion.	**Newton's second law of motion Weight Free-body diagram Gravitational attraction between masses**
Section 4 Projectile Motion: Launching Things into the Air Students explore the motion of objects that are projected in a gravitational field. Differences between objects being dropped, launched horizontally, and launched at an angle are explored in relation to the landing position of objects dropped straight down to those with projected motion.	**Gravity, Independence of right angle components, Trajectory of a projectile**
Section 5 The Range of Projectiles: The Shot Put Students compare mathematical and physical models of projectile motion to that of a shot put. They apply this to describe the vertical and horizontal motion of the projected object and predict its trajectory.	**Acceleration due to gravity, Range of a projectile, Mathematical versus physical models**
Section 6 Newton's Third Law: Run and Jump Thinking about the direction in which they apply force to move in a desired way introduces students to the concept that every force has an equal and opposite force. They test this concept and then apply it to a variety of motions observed in sports.	**Normal force Newton's third law Action-reaction pair forces Free-body diagrams Center of mass**
Section 7 Frictional Forces: The Mu of the Shoe Students measure the amount of force necessary to slide athletic shoes on a variety of surfaces. From this and the weight of the shoe, they learn to calculate friction coefficients. They then consider the effect of friction on an athlete's performance.	**Friction Coefficient of friction Normal force Weight**
Section 8 Potential and Kinetic Energy: Energy in the Pole Vault Students use a penny launched from a ruler to model motion during the pole vault. They connect their observations to the concept of energy conservation.	**Gravitational potential energy, Kinetic energy, Energy conversion, Law of conservation of energy, Work, Spring potential energy**
Section 9 Conservation of Energy: Defy Gravity Students learn to measure hang time and analyze vertical jumps of athletes using slow-motion videos. This introduces the concept that work when jumping is force applied against gravity.	**Gravitational potential energy, Kinetic energy, Energy conversions, Force and weight, Law of conservation of energy, Work, Spring potential energy**

Chapter 3: Safety

Chapter Challenge

Your design team will develop a safety system for protecting automobile, airplane, bicycle, motorcycle, or train passengers during a collision. To illustrate this safety system, you will design and build a prototype safety system to protect an egg in a moving cart that undergoes a collision. This prototype will then be tested to see how effectively it protects the egg.

Section Summaries	Physics Principles
Section 1 Accidents Students identify and evaluate safety features in automobiles. Students then consider what safety features they could use for various vehicles and for their design of a safety system.	**Identifying criteria for building a safety feature**
Section 2 Newton's First Law of Motion: Life and Death before and after Seat Belts Students explain what occurs to passengers during a collision using Newton's first law. They read about the concept of pressure and apply this concept while designing and testing a seat belt to safely secure a clay passenger in a cart undergoing a collision.	**Newton's first law** **Pressure**
Section 3 Energy and Work: Why Air Bags? Students investigate and observe how spreading the force of an impact over a greater distance reduces the amount of damage done to an egg during a collision. They describe and explain their observations using the work-energy theorem.	**Average velocity** **Newton's second law** **Work** **Kinetic energy** **Work-energy theorem**
Section 4 Newton's Second Law of Motion: The Rear-End Collision Students explore the effects of rear-end collisions on passengers, focusing on whiplash. They use Newton's laws to describe how whiplash occurs. They also describe, analyze, and explain situations involving collisions using Newton's first and second laws.	**Newton's first law** **Newton's second law**
Section 5 Momentum: Concentrating on Collisions After observing various collisions, students are introduced to the concept of momentum. Through measurements taken during various collisions they determine the mass of a cart. Students then calculate and consider the momentum of various objects.	**Linear motion** **Momentum**
Section 6 Conservation of Momentum Students investigate the law of conservation of momentum by measuring the masses and velocities of objects before and after collisions. Students then analyze various collisions by applying the law of conservation of momentum.	**Newton's second law** **Newton's third law** **Momentum** **Conservation of momentum**
Section 7 Impulse and Changes in Momentum: Crumple Zone Students design a device on the outside of a cart to absorb energy during a collision to assist in reducing the net force acting on passengers inside the vehicle. Students use probes to measure the velocity of the vehicle and the force acting on the vehicle during impact, and then describe the relationship between impulse ($F\Delta t$) and change in momentum ($m\Delta v$).	**Newton's second law** **Impulse** **Momentum** **Work-energy theorem**



Chapter 4: Thrills and Chills

Chapter Challenge

The *Chapter Challenge* is to modify the design of a roller coaster to meet the needs of a specific group of riders who would not normally ride the roller coaster. The design should include calculations to insure the safety of the ride and the energy needed for the ride to operate. A written report and a class presentation of a model of the roller coaster are necessary to complete the assignment.

Section Summaries	Physics Principles
Section 1 Velocity and Acceleration: The Big Thrill Students first investigate methods of making mechanical drawings. They then determine at which points during motion in class they notice changes that they associate with roller coasters. After defining velocity and acceleration, the students determine the velocity and acceleration of a steel ball as it rolls along different tracks using a velocity meter.	**Velocity** **Acceleration** **Acceleration due to gravity**
Section 2 Gravitational Potential Energy and Kinetic Energy: What Goes Up and What Comes Down Students discover the factors that determine the speed of a ball as it rolls on an incline. The students compare their results for the velocity of the ball rolling down the incline with the velocity of a pendulum swinging from different heights by graphing velocity squared versus height. The concepts of gravitational potential energy and kinetic energy are used to explain the similarity of results in the two cases. The law of conservation of energy is explored in the transformation of energy forms.	**Velocity versus distance** **Gravitational potential energy** **Kinetic energy** **Law of conservation of energy**
Section 3 Spring Potential Energy: More Energy Students use a spring "pop-up" toy to investigate spring potential energy stored in a compressed spring. Using the concepts of kinetic energy and gravitational potential energy, the students explore a more general form of the law of conservation of mechanical energy that includes the energy stored when springs with a known spring constant are compressed or stretched.	**Stoichiometry** **Gravitational potential energy** **Kinetic energy** **Spring potential energy** **Law of conservation of energy**
Section 4 Newton's Law of Universal Gravitation: The Ups and Downs of a Roller Coaster Students investigate how the force of gravity varies with distance from the center of Earth using data for the acceleration due to gravity at various points. By plotting a graph, the students determine the inverse square relationship between gravitational force and distance. The shape of Earth's gravitational field is noted. Newton's derivation of the gravitational force and how it shapes the orbits of celestial bodies is discussed.	**Acceleration due to gravity** **The force of gravity** **Inverse square relationships** **Earth's gravitational field**
Section 5 Hooke's Law: Your "At Rest" Weight Students explore the difference between mass and weight, and how the weight of an object depends upon the acceleration due to gravity. By using a spring, they determine how the stretch of the spring relates to the force applied to stretch or compress. By graphing their data, the students determine Hooke's law and how to calculate a spring constant. A spring is then used to determine the size of an unknown mass. Equilibrium of forces when multiple rectilinear forces act is discussed.	**Weight versus mass** **Force due to springs** **Hooke's law** **Equilibrium and Newton's laws**
Section 6 Forces Acting During Acceleration: Apparent Weight on a Roller Coaster Students use a spring scale to investigate the net force required for an object to travel upward and downward at a constant velocity. They then repeat the investigation to observe the net forces required for upward and downward acceleration. Newton's second law for net forces is used to analyze a free-body diagram for objects undergoing accelerations. The apparent weight experienced in an elevator is related to the acceleration an object undergoes due to the acting net force. Why the force of gravity accelerates all objects at the same rate is discussed.	**Newton's second law** **Free-body diagrams** **Apparent weight** **Acceleration due to gravity**
Section 7 Circular Motion: Riding on the Curves Students first investigate the motion of a battery-operated car under the influence of a centripetal force and then its motion when the force is released. They then identify the direction of the centripetal force, acceleration, and velocity for objects moving in circles. The students investigate the relationship between the centripetal force required to make an object move in a circular path, the mass and speed of the object, and the radius of the circle being traveled in both horizontal and vertical circles. The changing force required for a vertical circle is explored in depth in relation to Newton's second law.	**Tangential velocity** **Centripetal force** **Centripetal acceleration** **Apparent weight** **Net force** **Free-body diagrams** **Normal force**
Section 8 Work and Power: Getting to the Top Students pull up a fixed height by various paths to demonstrate the independence of the path on the work being done. The definition of work is then developed from the students' data and then related to gravitational potential energy. Uncertainty in measurement and the development of scientific principles from data is discussed. The relationship between work and power is discussed, and the formula for power is introduced.	**Work** **Work and energy** **Transformations** **Power** **Horsepower** **Measuring uncertainty**
Section 9 Force and Energy: Different Insights Students begin the section by developing concept maps on forces and energy relationships to organize their knowledge. The relationship between force and energy (work) is explored. Explicit examples of the principle of conservation of energy are explored for various points on the roller coaster. Energy as a scalar allowing ease of analysis is explored, as well as situations where energy alone does not provide sufficient information and force considerations are appropriate. The students do an exercise using vectors to locate the position of an object.	**Gravitational potential energy** **Spring potential energy** **Kinetic energy** **Work** **Vectors and scalars** **Vector addition** **Forces**
Section 10 Safety Is Required but Thrills Are Desired Students investigate parameters that determine what limits are placed on their design. Students do calculations on centripetal force, apparent weight, normal force, and the net force acting on the roller coaster cars at various points to determine the forces acting on the coaster car.	**Force, Newton's second law,** **Centripetal force,** **Centripetal acceleration,** **Normal force, Apparent weight,** **Net force**

Chapter 5: Let Us Entertain You

Chapter Challenge

The *Chapter Challenge* is to design a sound and light show to entertain students your age. The sounds must come from musical instruments, human voices, or sound makers you build and the light from a laser or conventional lamps. An explanation of the physics principles involved in your show will also be required.

Section Summaries	Physics Principles
Section 1 Sounds in Vibrating Strings To connect vibrations and waves to sound, the students observe the vibration of a plucked string and investigate how the pitch varies with the length of the string. They then explore how the tension of the string affects the vibration rate and the pitch.	**Sound and vibration** **Vibrations on strings** **Sound and tension** **Sound and string length** **Pitch and frequency**
Section 2 Making Waves By making waves with coiled springs, students observe transverse and longitudinal waves, periodic wave pulses, and standing waves. The students investigate the relationship between wave speed and amplitude, the effect of a medium on wave speed, and when waves meet, wave addition (or the principle of superposition). Using standing waves, the students develop the relationship between wave speed, frequency, and velocity.	**Periodic waves** **Wave pulse** **Transverse waves** **Longitudinal waves** **Standing waves** **Principle of superposition**
Section 3 Sounds in Strings Revisited Students return to vibrating strings, interpreting what they observed in *Section 1* in terms of standing waves, wavelength, and the frequency of a vibrating string. The students then apply the wave equation to human motion, where speed equals stride length times frequency.	**Wavelength** **Frequency** **Wave speed**
Section 4 Sounds from Vibrating Air Drinking straws and test tubes partially filled with water are used to model wind instruments that use columns of vibrating air to produce sounds. The students investigate the relationship of pitch to the length of the vibrating column of air in longitudinal waves. Diffraction of waves is investigated as a method to transmit sound from the vibrating air column to its surroundings.	**Longitudinal waves** **Frequency** **Wavelength** **Diffractiony** **Absolute zero**
Section 5 Shadows In this section, students investigate how shadows are produced. The rectilinear nature of light rays is used to investigate how to produce the umbra and penumbra shadows of extended light sources.	**Light travels in straight lines** **Shadows** **Umbra** **Penumbra**
Section 6 Reflected Light Students explore how plane mirrors reflect light rays. First investigating how changing the angle of incidence affects the angle of reflection, the students use this to build up a model of how images are formed by plane mirrors.	**Angle of incidence** **Angle of reflection** **Normal** **Virtual images** **Transverse waves**
Section 7 Curved Mirrors Students explore how light rays reflect from convex and concave mirrors using a laser pointer. They investigate how a convex mirror is able to focus light, and how this property allows convex mirrors to focus light rays to produce real images. The relationship between the distance of the real image formed from the mirror, the object distance, and the mirrors' focal length is discovered. Virtual images formed by both the convex and concave mirror are also discussed.	**Concave mirror** **Convex mirror** **Real image** **Virtual image** **Focal point** **Light rays**
Section 8 Refraction of Light Using a laser pointer, the students send a ray of light through an acrylic block to explore how light refracts as it passes from one transparent medium to another. By measuring the angle of incidence and the angle of refraction, the students develop the concept of the index of refraction. As the angle of incidence approaches the critical angle, total internal reflection in a prism is explored.	**Angle of incidence** **Angle of refraction** **Normal** **Index of refraction** **Snell's law** **Total internal reflection** **Critical angle**
Section 9 Effect of Lenses on Light By shining light through a convex lens and locating the image formed at different positions of the light source, the students develop an understanding of how real images are formed by convex lenses. By projecting different sizes of images of the light source onto a surface, the students explore how images are formed and used in everyday equipment. Ray diagrams, as a method to predict image size and location are discussed, while *Active Physics Plus* further develops the lens equation.	**Convex lens** **Real images** **Virtual images** **Ray diagrams** **Focal point** **Lens equation**
Section 10 Color Students investigate colored shadows formed by multiple light sources using additive primary colors. By carefully tracing the light rays from different sources, the students investigate the colored shadows that are formed and how added light produces different colors. Subtractive primaries are also investigated.	**Light rays** **Primary colors** **Color addition**

Chapter 6: Electricity for Everyone

Chapter Challenge

The *Chapter Challenge* is to design an appliance package for a family that is powered by a wind-driven generator. The constraints are that no part of the package can draw more than 2400 W and the average daily consumption should not exceed 3 kWh. In addition, you will construct a training manual explaining the basic principles of electricity for the family, including a wiring diagram with the locations of outlets and switches.

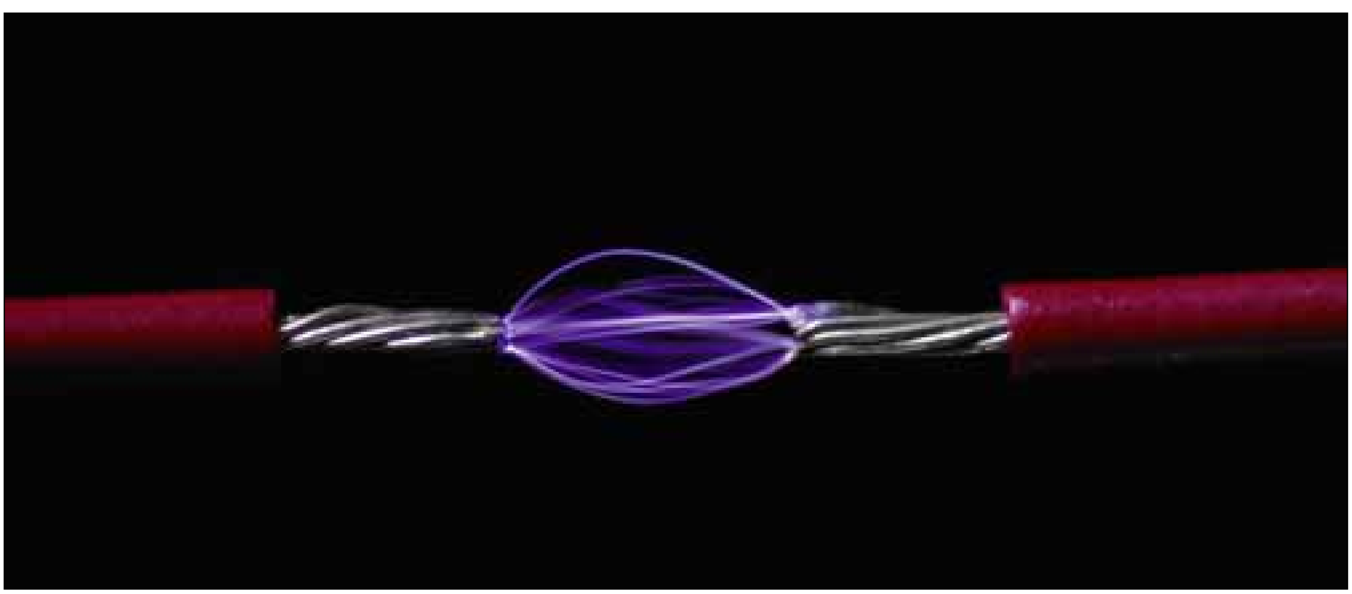
Section Summaries	Physics Principles
Section 1 Generating Electricity With a simple hand generator, wires, and light bulbs, students investigate electric circuits and electrical energy. Using the hand generator introduces them to the concept that electricity is the result of converting one form of energy into another. The operation of a light bulb is also investigated.	**Electricity** **Generator** **Closed circuit** **Energy sources**
Section 2 Modeling Electricity: The Electron Shuffle Students develop a qualitative model of electricity, including how current flows in series and parallel circuits, and how electrical energy is delivered to devices by playing the part of electric charges as they move through a circuit.	**Electric charge (coulomb),** **Electric energy,** **Electric current,** **Resistance,** **Series circuit, Circuit symbols**
Section 3 Series and Parallel Circuits: Lighten Up The Electron Shuffle model is used again to investigate current, resistance, and how electrical energy behaves in a parallel circuit. Comparisons between series and parallel circuits are investigated. Fundamental charges are also discussed.	**Series circuit** **Parallel circuit** **Electric energy** **Electric current** **Resistance** **Fundamental charges**
Section 4 Ohm's Law: Putting Up a Resistance Students design an experiment to determine the resistance of an unknown resistor. Proper use of a voltmeter and ammeter are discussed, and the students set up a series circuit to determine the current for a series of voltages applied to the resistor. Graphing the relationship between voltage and current for a resistor demonstrates Ohm's law. The process is repeated for other resistors, and then for an unknown.	**Voltage** **Current** **Resistance** **Voltmeter** **Ammeter** **Black box**
Section 5 Electric Power: Load Limit Students create a simple fuse to see how fuses work. The teacher then connects a group of appliances to a power strip until a fuse in the circuit blows. The students then calculate the load limit of a household circuit and the watts required by appliances, comparing these to the limits given in the challenge. This also introduces the use of terms and equations for calculating power.	**Voltage** **Current** **Power** **Power rating** **Load limit**
Section 6 Current, Voltage, and Resistance in Parallel and Series Circuits: Who's in Control? Students assemble a parallel circuit to explore how switches control the flow of electricity through various sections of the circuit. They then use a voltmeter and ammeter to determine the voltage and current for the elements of a parallel circuit, as well as the circuit as a whole. Finally, they mathematically examine voltage, current flow, and total resistance in series and parallel circuits, while being introduced to circuit diagrams.	**Switches** **Parallel circuit** **Series circuit** **Voltage equations** **Current equations** **Resistance equations** **Power equations** **Circuit analysis**
Section 7 Laws of Thermodynamics: Too Hot, Too Cold, Just Right Students investigate the laws of heat transfer by mixing hot and cold water in different proportions. The concept of specific heat is developed as the students use hot metal to warm cold water. Conservation of energy is then discussed as the students calculate energy transfers between various materials. The difference between heat and temperature is emphasized while the laws of thermodynamics and entropy are discussed.	**Heat transfer** **Temperature** **Specific heat** **Zeroth law of thermodynamics** **First law of thermodynamics** **Entropy** **Second law of thermodynamics** **Heat engines**
Section 8 Energy Consumption: Cold Shower Electricity used by water heaters is the focus of this activity, which also reinforces concepts of energy transfer. Students investigate the amount of energy in joules needed to raise the temperature of water, and then calculate the efficiency of different water heaters. They also consider alternate solutions to the expectation of hot water in a home.	**Heat transfer** **Electric energy** **Voltage** **Current** **Power, Efficiency**
Section 9 Comparing Energy Consumption: More for Your Money Students conduct an experiment in which they determine and compare the power consumption and efficiency of three systems that could be used to heat water. They apply collected data to confirm their response to the challenge in which they recommend appliances for the universal home. Methods of heat transfer are discussed, including convection, conduction, and radiation.	**Heat transfer** **Electric energy** **Power** **Efficiency** **Convection** **Conduction** **Radiation**

Chapter 7: Toys for Understanding

Chapter Challenge

The *Chapter Challenge* is to design a toy that employs either a motor or a generator as a fun device to teach children about how generators and electric motors work. An instruction manual should be developed that explains how to assemble the toy and the basic physics principles of how and why it works.

Section Summaries	Physics Principles
Section 1 The Electricity and Magnetism Connection Students explore the forces of magnetic attraction and repulsion as well as the magnetic properties of ferrous materials. They then plot the magnetic field of a bar magnet using a compass and iron filings. Students investigate the relationship between electricity and magnetism by using a compass to test for the magnetic field produced by a current-carrying wire. A method to predict the direction of the magnetic field around a current-carrying wire using the left hand is discussed.	**Magnetic field** **Magnet** **Compass** **Left-hand rule**
Section 2 Electromagnets Using a hand generator to power an electromagnet is the first step in a continuing investigation into the relationship between electricity and magnetism. Students test the strength and find the polarity of electromagnets made with different core materials and different currents.	**Solenoid** **Magnetic polarity** **Core material**
Section 3 Building an Electric Motor Students construct and operate a DC motor. They also read about how a DC motor works, and how a commutator is necessary to operate a DC motor.	**DC motor** **Commutator** **Force on a current-carrying conductor**
Section 4 Detect and Induce Currents Students construct a galvanometer by using the fact that a compass can detect the presence of a magnetic field. They will use a permanent magnet and a solenoid to create an induced current by manually alternating the motion of a magnet in a fashion similar to the process used by Faraday and Henry. Using the galvanometer to detect the induced current, they will explore the need for relative motion between magnetic fields and wires.	**Galvanometer** **Induced voltage** **Lenz's law** **Field lines**
Section 5 AC and DC Currents Producing an electric generator by rotating a coil of wire in a magnetic field is explored. Students learn the difference between how AC and DC currents are generated by considering both types of electric generators and analyzing the induced currents in their rotating coils. Students read about how a commutator changes AC electricity into DC electricity. Students also learn how to sketch output waveforms.	**Electric generator** **AC electricity** **DC electricity** **Commutator** **Waveforms**
Section 6 Electromagnetic Spectrum: Maxwell's Great Synthesis Students start by classifying groups as a way to identify patterns. The students look at the relationships between electricity and magnetism they have studied and try to find a pattern. A discussion of the pattern discovered by Maxwell and his discovery that all electromagnetic waves travel at the speed of light is discussed. Several experiments that attempted to calculate the speed of light are also discussed. The students conclude by reading about the electromagnetic spectrum.	**Maxwell's equations** **The speed of light** **The electromagnetic spectrum**



Chapter 8: Atoms on Display

Chapter Challenge

The *Chapter Challenge* is to develop a museum exhibit to acquaint visitors with aspects of the atom that they will see throughout the museum. An introductory and concluding poster about the exhibits, as well as written matter about the exhibit you designed, should be included.

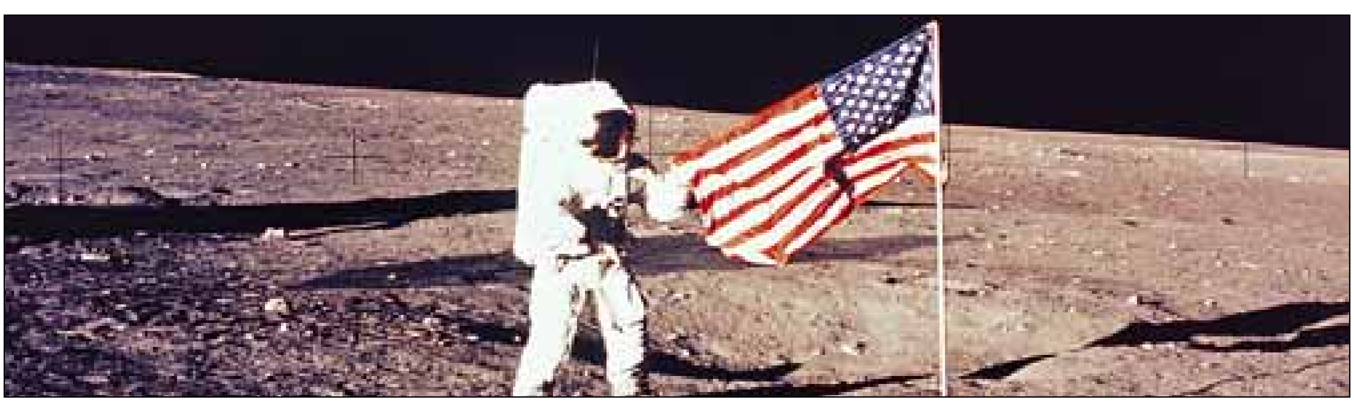
Section Summaries	Physics Principles
Section 1 Static Electricity and Coulomb's Law: Opposites Attract Using transparent cellophane tape, students investigate the static electricity of charged objects. Inductive electric forces are explored and the students read about conservation of charge and Coulomb's law to prepare them to understand the forces holding an atom together.	Electric fields Charge Conservation of charge Coulomb's law Grounding, Induction
Section 2 The Nature of Charge: Tiny and Indivisible In a simulation of Millikan's oil-drop experiment, students use inquiry to find the number of coins enclosed in a film canister. They then learn how related techniques were used to determine that electric charge is quantized. The process of inference to obtain information about systems that cannot be directly measured is used.	Quantization of charge Charge on the electron Millikan experiment
Section 3 The Size of a Nucleus: How Big Is Small? Using statistical measurements, students estimate the size of a penny. They then compare their statistical approach with direct measurement. Finally, they compare their experiment with Rutherford's experiment to determine the size of a nucleus in relation to an atom and the evidence we have to verify that knowledge.	Atomic models Atomic nucleus Atomic forces Atom as mostly empty space
Section 4 Hydrogen Spectra and Bohr's Model of the Hydrogen Atom Students investigate spectral lines by using a spectrometer to measure the wavelengths of light emitted by three gases. The unique spectra of atoms are discussed and the students then learn about the Bohr model of the atom. Using this model, they calculate the wavelengths of light emitted as electrons jump from one quantized orbit to another. The discovery of helium from its spectrum is discussed. In the *Active Physics Plus*, the formula for the energy of a photon is also discussed.	Bohr model Quantized electron orbits Atomic spectra Electron energy levels Balmer series
Section 5 Wave-Particle Model of Light: Two Models Are Better Than One! The wave and particle nature of light is explored by investigating two-slit interference and the photoelectric effect. By drawing an analogy to standing waves on a string, a new interpretation of the Bohr orbit as standing waves of electrons is introduced, with a nonmathematical introduction of the Schrödinger wave equation. The dual wave and particle nature of electrons is also discussed.	Interference of waves Photoelectric effect Work function Photon energy Photon model of light Schrödinger wave equation DeBroglie waves
Section 6 The Strong Force: Inside the Nucleus The proton-neutron model of the nucleus is introduced and explored. With a huge Coulomb repulsion pushing protons apart, the need for a strong attractive force in the nucleus is investigated. Students are then introduced to Feynman diagrams as a means of understanding how forces are transmitted.	Proton-neutron model Strong force Feynman diagram Action at a distance Virtual particles
Section 7 Radioactive Decay and the Nucleus Students investigate the statistical properties of randomly tossing marked cubes. They then relate these results to the statistics of radioactive decay. The concept of half-life is introduced as a clock for measuring radioactive decay. Students are then introduced to complete nuclear equations for alpha, beta, and gamma decays.	Radioactive decay Half-life Atomic mass Atomic number Nuclear transmutation
Section 8 Energy Stored within the Nucleus Students are introduced to Einstein's famous equation $E = mc^2$ and use it to calculate the energy liberated by the conversion of mass to energy. After calculating the mass defect of the nucleus, the equation is used to calculate nuclear binding energies.	Atomic mass unit Conservation of mass energy Nuclear mass defect Nuclear binding energy Particle-antiparticle annihilation
Section 9 Nuclear Fission and Fusion: Breaking Up Is Hard to Do Students start by calculating the nuclear binding energy of various elements and then graph the binding energy per nucleon versus the element's atomic number. Students explore nuclear fission and fusion reactions. How a fission chain reaction works is also studied.	Binding energy per nucleon Nuclear fission Nuclear fusion

Chapter 9: Sports on the Moon

Chapter Challenge

The *Chapter Challenge* is to develop a proposal for NASA by either adapting or inventing a sport that can be played on the surface of the Moon with its reduced gravity. Writing a local newspaper article describing the championship match for your sport is also required.

Section Summaries	Physics Principles
Section 1 Identifying and Classifying: What Is a Sport? Students apply their knowledge of sports to identify attributes that define an activity as a sport. From this, they begin to consider how differences between Earth and the Moon can affect sports.	**Pattern identification**
Section 2 Acceleration Due to Gravity: Free Fall on the Moon Students compare the free fall of different objects. They then calculate acceleration with respect to gravity on the Moon using measurements obtained from a slow-motion video of an astronaut in space dropping objects.	**Gravity** **Acceleration** **Distance covered by accelerating objects**
Section 3 Mass, Weight, and Gravity Using a simulation that allows for the comparison of mass and weight between Earth and the Moon, students investigate the ratio of gravity on Earth to that on the Moon. After determining that an object's inertia does not change, the forces needed to overcome weight and inertia on the Moon are discussed.	**Inertia** **Weight** **Universal law of gravitation** **Newton's second law**
Section 4 Projectile Motion on the Moon Beginning with scale drawings, students calculate the distances that projected objects will travel on the Moon. These distances are then compared to projectiles launched on Earth with the same velocity to determine how sports that use projectiles would be changed on the Moon.	**Projectile motion** **Gravity**
Section 5 Gravity, Work, and Energy: Jumping on the Moon Students measure vertical distances when jumping and then analyze their motion in terms of work and conservation of energy. Applying what they know about gravity on the Moon, they predict vertical distances they could jump on the Moon.	**Work** **Gravitational potential energy** **Kinetic energy** **Conservation of energy**
Section 6 Momentum and Gravity: Golf on the Moon Using a variety of balls, students measure the height each bounces when dropped and when projected by a collision. They use this data to infer a golf ball's speed when hit on Earth and on the Moon. The interaction of different golf clubs and golf balls with varying degrees of mass is also investigated.	**Gravitational potential energy** **Kinetic energy**
Section 7 Friction: Sliding on the Moon Students investigate the force necessary to overcome the friction between objects and the surfaces on which they move. They then relate this to gravity and predict the force needed to overcome the friction against a sliding motion made on the Moon.	**Weight** **Friction** **Coefficient of friction** **Normal force** **Newton's second law**
Section 8 Vibration and Rotation: Bounding on the Moon Using cylinders of different lengths and weights, students explore pendulum motion. They then compare the motion of the pendulums to the swinging motion of human legs when walking, finally predicting how walking on the Moon and on Earth is different.	**Gravitational field strength** **Simple harmonic motion** **Period of a pendulum**
Section 9 Air Resistance and Terminal Velocity: "Airy" Indoor Sports on the Moon Students start by investigating how mass and terminal velocity are related. They then use badminton shuttlecocks to investigate how air resistance affects motion. They then apply what they know about the ratio of gravity on Earth to that of the Moon to predict the air resistance to motion on the Moon.	**Air resistance** **Terminal velocity**



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