Annenberg/CPB
Professional Development Workshop Guide

Science in Focus

Force and Motion

An eight-part professional development workshop
for elementary and middle school science teachers

Produced by the Harvard-Smithsonian Center for Astrophysics

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About the Workshop

Workshop Overview

In this workshop, teachers will explore science concepts in force and motion and come away with a deeper understanding that will help them engage students in their own explorations.

The study of force and motion really begins the first time a child picks up something or notices something move. If children are using high-quality instructional materials, they will have numerous opportunities to drop, slide, roll, float, and balance various objects and observe how the objects behave. They will also be encouraged to compare the results of these school-based investigations to their real-life experiences.

Students come to the classroom with deep-seated intuitive views about how the world works. Their K-12 science lessons should allow them to explore their own notions about common, everyday phenomena, discuss their observations with peers, and draw conclusions that can be tested. Since force and motion encompass phenomena that relate directly to the student's world, they provide a content area in which students can make predictions, practice data collection and graphing techniques, and start to make scientific sense of their observations. This also provides students with an opportunity to apply some of their growing mathematical understanding.

This content workshop consists of eight one-hour professional development programs. Each program features footage from a complete science lesson related to force and motion. These lessons, virtually unedited, take place in real classrooms across the grade levels. As children explore the relationships among motion, force, size, mass, and speed, the camera captures the students' ideas and how they change and build during the activity and subsequent discussion.

As each classroom lesson unfolds, science and education experts act as guides, highlighting and expanding on the key points that emerge. Their commentary, coupled with graphics and video demonstrations, reinforces the science concepts taught in the lessons, and supplements the lessons with background information about gravity, friction, air resistance, magnetism, and tension. As the students begin to connect science concepts to real-world phenomena, teachers will be asked to think about their own ideas on force and motion.

The lessons teachers observe in the video and the activities they do in this workshop will provide them with the opportunity to test some of their own initial ideas about force and motion. The goal is to move teachers toward a greater understanding of forces as interactions, the concept of action at a distance, the various ways to describe motion, and the effect of physical surroundings on the motion of objects.

About the Workshop, cont'd.

Workshop Goals

Concepts

You will:

- ❒ Develop an understanding of forces as interactions.
- ❒ Develop the ability to analyze the forces acting on objects.
- ❒ Develop the ability to analyze the motion of objects.
- ❒ Develop an appreciation for Newton's Laws of Motion.

Skills

You will learn to:

- ❒ Identify and represent forces, including:

  Contact Forces:

  - Active pushes or pulls (e.g., by the human body, rubber bands, or springs)
  - Passive pushes or pulls (e.g., by floor or rope)
  - Friction (e.g., sliding, rolling, or fluid resistance)

  Non-Contact Forces:

  - Gravitational, electrical, and magnetic forces

- ❒ Explain the forces acting on objects that are:
  - At rest
  - Moving with a constant speed
  - Moving with a constant acceleration

- ❒ Describe and explain (using words, pictures, data tables, and graphs) the motion of objects in one dimension, including:
  - Linear horizontal or vertical motion
  - Falling, with and without air resistance
  - Motion on an inclined plane (e.g., rolling and sliding)

- ❒ Describe the motion of objects using appropriate terms including:
  - Instant in time
  - Interval of time
  - Position
  - Instantaneous speed
  - Mass
  - Acceleration

- ❒ Develop a familiarity with terms related to force and motion including:
  - Inertia
  - Vector
  - Pressure
  - Stability
  - Net force
  - Scaling
  - Frame of reference
  - Power

About the Workshop, cont'd.

Workshop Descriptions

Workshop 1. Making an Impact

What would happen if an asteroid were to hit the surface of the Earth? How large a crater would the impact create? In this workshop, the ideas of force and motion are introduced, as seventh-grade students drop balls to simulate asteroid impacts. By varying a ball's mass, the height from which it is dropped, or the material being struck, the students explore what factors affect the size of the crater. They also learn about data collection and the proper use of measurement units.

Featured Classroom: Morse School, Cambridge, Massachusetts
Teacher Karen Spaulding's seventh-grade students model meteorite impacts by dropping balls of varying mass from different heights onto different surfaces and recording their results.

Visualizations: How Are Size, Mass, and Speed Related to Force?
Through video demonstrations and commentary, we explore the difference between mass and weight, whether objects of different masses fall at different speeds, and how quickly falling objects come to rest.

Workshop 2. Drag Races

Forces can help put objects into motion and can also bring moving objects to a stop. In this workshop, fifth-grade students explore the physics of motion using plastic cars with strings and washers attached to provide a pulling force. The students test the speed of the vehicles and explain what forces bring the vehicles to a stop, as the cars collide with and displace barriers at the end of their run. Finally, the students discuss their findings to help solidify their understanding of the effect of forces on motion.

Featured Classroom: Armstrong School, Westborough, Massachusetts
Barbara Mitchell's fifth-grade class discovers how model cars can be moved by falling weights (washers hung by a string). The students make predictions about the motion and test what forces bring their vehicles to a stop.

Visualizations: How Will a Constant Force Affect Motion?
Video and graphic demonstrations provide an introduction to the concepts of friction, vectors, and acceleration under different experimental conditions.

Workshop 3. When Rubber Meets the Road

A rubber band twisted around the axle of a plastic car provides the force that moves the car forward. In this workshop, fifth-grade students continue their exploration of force and motion by recording and comparing the distance a vehicle travels under various conditions. Students predict the distance the car will travel by counting the number of twists in the rubber band, and observe the car's speed as it rolls across the floor. When the force of the rubber band stops acting, the force of friction slows the car to a stop.

Featured Classroom: Armstrong School, Westborough, Massachusetts
Continuing their investigation, Barbara Mitchell's students explore the motion of rubber-band-powered vehicles, relating the number of twists in the rubber band to the distance and speed of travel.

Visualizations: How Will a Changing Force Affect Motion?
Demonstrations further illustrate vectors, frictional forces, and factors that may cause changes in acceleration or bring an object to rest.

About the Workshop, cont'd.

Workshop 4. On a Roll

The force of gravity makes a ball roll when it is placed on an incline. In this workshop, first-grade students roll balls of different sizes, masses, and materials down ramps of varying heights, comparing their speeds. The students then experiment by replacing the ramp with a cardboard tube, and try to determine how the tube must be oriented to allow the ball to roll, much as it rolled down the ramp.

Featured Classroom: Laurel Lake School, Fall River, Massachusetts
In this workshop, Joanne Aguiar's first-grade students roll balls of various sizes, masses, and materials down ramps and compare patterns of motion.

Visualizations: How Do Size and Mass Affect Motion?
Expanding on their observations, we investigate changes in motion as a result of different forces under different conditions.

Workshop 5. Keep On Rolling

Roller coasters are filled with twists and turns, as changes in height and direction supply a variety of push and pull forces. In this workshop, first-grade students build on their prior experience with rolling objects. By designing and constructing their own roller coaster made from ramps, cardboard tubes, and flexible tubes, the students experiment with ways to get a marble from the top of a table into a bucket on the floor, some distance away.

Featured Classroom: Laurel Lake School, Fall River, Massachusetts
Joanne Aguiar's first-graders continue to explore rolling motion, using ramps, tubes, and changes in height and direction to design and construct their own roller coasters.

Visualizations: How Does Changing the Angle Affect the Motion on an Inclined Plane?
Using the class activities as a springboard, we investigate the forces acting upon objects on both inclined planes and flat surfaces.

Workshop 6. Force Against Force

Magnets stick to other magnets and to metal objects made of iron or steel. How much force is required to break the attraction between two magnets? In this workshop, fourth-grade students explore ways to balance the force of magnetism against the force of gravity. A magnet placed in a cup on one side of a pan-balance is stuck to a stationary magnet beneath the cup. When enough washers are placed on the opposite side of the balance, the magnets will separate. Graphical analysis shows some unexpected results.

Featured Classroom: Harwich Elementary School, Harwich, Massachusetts
Janet Smithers' fourth-grade students explore the strength of magnetic force as they try to break the force of attraction by countering it with the force of gravity.

Visualizations: How Do You Measure Unseen Forces?
Expanding on the classroom work, we explore the force of attraction between magnets and how to quantify these forces.

About the Workshop, cont'd.

Workshop 7. The Lure of Magnetism

What is the difference between a permanent magnet and an electromagnet? In this workshop, fourth-grade students build an electromagnet by winding a wire around a rivet and attaching the ends to battery terminals. The students first predict how many washers they can pick up with the help of their electromagnet and then perform the experiment to test their predictions. After the number of washers is recorded and the results are discussed, the students engage in a group discussion about practical uses for electromagnets.

Featured Classroom: Harwich Elementary School, Harwich, Massachusetts
Janet Smithers' fourth-graders continue their investigation of magnetism. Working with electromagnets, they change the number of windings of the wire around the metal core, make predictions, and test their results.

Visualizations: How Do Permanent Magnets and Electromagnets Differ?
In this workshop, we learn how to control the force of electromagnets and how electromagnets differ from permanent magnets. We also explore how previous workshop ideas fit into Newton's Laws of Motion.

Workshop 8. Bend and Stretch

We all expect a spring to stretch or compress when a force is applied, but forces can even deform solid objects like the floor or the top of a table. In this workshop, students in a high school classroom explore ideas about tension and normal force. By applying a force to a spring and measuring the distance the spring is stretched, the students calculate the force constant or stretchiness of the spring. Lecture demonstrations using student volunteers help illustrate that even rigid objects bend when a force is applied.

Featured Classroom: Newton North High School, Newton, Massachusetts
Led by Paul Martenis, high school students explore how force can bend and stretch stationary objects, working with springs, rubber bands, suspended weights, and lasers on a tabletop.

Visualizations: How Can Force Deform an Object?
Science demonstrations expand on the students' work and help us visualize the deformation caused by force. We investigate the force produced by stretched and compressed objects when released.

Workshop Components

On-Site Activities

Weekly workshop sessions may be scheduled around live broadcasts, in which case you will want to begin at least 30 minutes before the scheduled broadcast. You may prefer to pre-record the programs on videocassette, and schedule the sessions at a time that is more convenient for all participants. Sessions should be scheduled for a minimum of two hours.

This guide provides activities and discussion topics for pre- and post-viewing investigations that complement that weekly programs. See Helpful Hints on the following page for information on preparing for your Site Investigations.

Getting Ready (Site Investigation)

In preparation for watching the program, you will engage in 30 minutes of investigation through discussion and activity.

Watch the Workshop Video

Then you will watch 60 minutes of video with classroom footage, commentary, science demonstrations, and more.

Going Further (Site Investigation)

Wrap up the workshop with an additional 30 minutes of investigation through discussion and activity.

For Next Time

Homework Assignment

You will be assigned exercises and activities that tie into the last workshop or prepare you for the next one.

The 10-Cent Experiment

Each workshop video presents a simple hands-on activity that you can do on your own, using readily available materials, to investigate a science concept. Or, you can simply watch the demonstration and ponder the unanswered question it poses.

Workshop Journal

A critical part of taking steps toward change is representing learning along the way. This is a deliberate process that calls for reflecting upon your own understandings before, during, and after key experiences, and documenting how these understandings change. While there are numerous ways to represent learning, we suggest using a journal. As the workshops progress, pay particular attention to changes in your thinking, and the implications of these changes, and record them in your journal.

Workshop Web Site: http://www.learner.org/channel/workshops/force

Go online for additional activities, resources, and discussion.

Channel-TalkForce

You can communicate with other workshop participants via email. To subscribe to Channel-TalkForce@learner.org (the workshop email discussion list), visit:

http://www.learner.org/mailman/listinfo/channel-talkforce

About the Site Investigations

Helpful Hints

Included in the materials for each workshop you will find detailed instructions for the content of your Getting Ready and Going Further activities (Site Investigations). The following hints are intended to help you and your colleagues get the most out of these pre- and post-video discussions.

Designate a Facilitator

Each week, one person should be responsible for facilitating the Site Investigations (or you might select two people—one to facilitate Getting Ready, the other to facilitate Going Further). The facilitator does not need to be the Site Leader, nor does it need to be the same person(s) each week. We recommend that participants rotate the role of facilitator on a weekly basis.

Review the Site Investigations and Bring the Necessary Materials

Be sure to read over the Getting Ready and Going Further sections of your materials before arriving at each workshop. The Site Investigations will be the most productive if you and your colleagues come to the workshops prepared for the discussions. A few of the Site Investigations require special materials. The facilitator should be responsible for bringing these when necessary. **You will need some of these materials for Workshop 1.** A complete materials list is on the following page, and materials are also listed for each workshop.

Keep an Eye on the Time

Thirty minutes go by very quickly, and it is easy to lose track of the time. You should keep an eye on the clock so that you are able to get through everything before the workshop video begins. You may want to set a small alarm clock or kitchen timer before you begin the Getting Ready Site Investigation to ensure that you won't miss the beginning of the video. (Sites that are watching the workshops on videotape will have more flexibility if their Site Investigations run longer than expected.)

Record Your Discussions

We recommend that someone take notes during each Site Discussion, or, even better, that you make an audiotape recording of the discussions each week. These notes and/or audiotape can serve as "make-up" materials in case anyone misses a workshop.

Share Your Discussions on the Internet

The Site Investigations are merely a starting point. We encourage you to continue your discussions with participants from other sites on the discussion area of the Web site and on Channel-TalkForce, the workshop email discussion list.

About the Site Investigations, cont'd.

Materials Needed

Note: You may want to do the 10-Cent Experiments at home. In that case, you would not need to bring those materials to the workshop sessions.

Workshop 1

A paper cup
A rubber band
Small objects for weighing

For the 10-Cent Experiment:
A marble
A muffin baking paper or a coffee filter

Workshop 2

For the 10-Cent Experiment:
Two raw eggs
A container of sand (depth of at least 6 inches)
A tile or other hard, flat surface

Workshop 3

Graph paper

For the 10-Cent Experiment:
A toy car
A smooth board
A stopwatch
Flat objects with different surface textures, such as:

- Sandpaper
- A dish towel

Workshop 4

Paper

For the 10-Cent Experiment:
A smooth board
Three identically sized soup cans:

- A can of thick soup, such as split pea
- A can of broth
- An empty can (with the top and bottom removed)

Workshop 5

For the 10-Cent Experiment:
A smooth board
Two wooden toy blocks, one twice as long as the other

Workshop 6

A non-carpeted floor
Two chairs, preferably with wheels
A rope or cord at least 4 to 6 meters long

For the 10-Cent Experiment:
Four small ring magnets
A pencil

Workshop 7

A 1.5-volt battery
A 2-inch or longer nail
1 yard of thin insulated wire remove any insulation from the ends)
A box of paper clips

For the 10-Cent Experiment:
Five identical rubber bands
Two paper clips
A ruler
A set of keys (or other object that can act as a weight)

Workshop 8

Your poster from Workshop 7's homework

(Site Leaders: Please bring copies of participants' questionnaires from Workshop 1)

For the 10-Cent Experiment:
A coiled spring
A ball (of proportionate size, to rest on top of the spring)

About the Contributors

Content Advisors

Paul Hickman worked as an engineer and taught high school physics in Cold Spring Harbor, New York, and Belmont, Massachusetts. He is currently a curriculum specialist at Northeastern University's Center for the Enhancement of Science and Mathematics Education (CESAME), and helps teachers to advance K-12 educational reform. He received the Presidential Award for Excellence in Science Teaching, the Tandy Technology Scholars Award, and the American Association of Physics Teachers' Award for Excellence in Pre-College Physics Education. Hickman has been involved with several national programs to improve science teaching and learning, has written for numerous professional journals, and has given talks and workshops for teachers nationwide. He received his B.S. in physics from Manhattan College and his M.S. from Long Island University.

Jennifer Bond Hickman, Ed.D., taught physics and astronomy at the Pomfret School in Connecticut, at Phillips Academy in Andover, Massachusetts, and most recently at Boston University Academy, where she also served as head of school. Dr. Hickman has served on the boards of several physics and astronomy organizations and is currently on the board of Boston's Hayden Planetarium. She has worked on numerous national curriculum development projects in science and has given talks and workshops around the country. Dr. Hickman is a recipient of the Presidential Award for Excellence in Science Teaching and the Tandy Technology Scholars Award, and is the author of *Problem-Solving Exercises in Physics*. She received her B.A. in physics and astronomy from Wellesley College, her M.S. from Worcester Polytechnic Institute, and her Ed.D. and MBA from Boston University.

Hosts

Sallie Baliunas, Ph.D., is an astrophysicist at the Harvard-Smithsonian Center for Astrophysics. She is deputy director and director of science programs at Mount Wilson Observatory; she also serves as senior scientist at the George C. Marshall Institute in Washington, D.C., and chairs the Institute's Science Advisory Board. Dr. Baliunas has written over 200 scientific research articles, and has received the Newton-Lacy-Pierce Prize of the American Astronomical Society, the Petr Beckmann Award for Scientific Freedom, and the Bok Prize from Harvard University. In 1991, *Discover* magazine profiled her as one of America's outstanding women scientists. Dr. Baliunas is a contributing editor to *World Climate Report* and a receiving editor for *New Astronomy,* and has been science advisor for the science-fiction series, *Gene Roddenberry's Earth: Final Conflict,* which has been airing since Fall 1997. Dr. Baliunas received her Ph.D. in astrophysics from Harvard University. Her research interests include solar variability and other factors in climate change.

Katy Abel has covered education and parenting issues in broadcast television, on the Internet, and in print for the past decade. She is currently a writer for Familyeducation.com, part of Pearson's Learning Network, one of the top 50 most-visited Web sites on the Internet. For many years, Abel was a reporter, producer, and public affairs host at WHDH-TV, Boston's NBC affiliate. She also wrote a monthly column for the *Boston Parents' Paper.* Her "Family First" reports were a regular feature on the CBS Early Show with Bryant Gumbel and Jane Clayson. Abel has also produced reports for The Learning Channel's "Teacher TV" series and hosted a live, interactive program for teens, "Student Forum," beamed via satellite to high schools throughout New England via the Massachusetts Corporation for Educational Telecommunications (MCET).

Classroom Teachers

Karen Spaulding has taught sixth-, seventh-, and eighth-grade science at the Morse School, Cambridge, Massachusetts, for seven years. As a teacher leader in the Cambridge Public Schools, Spaulding supports other middle school science teachers in this diverse urban district while maintaining a full-time teaching load. Her leadership work includes curriculum development, assessment, grant writing, designing and carrying out professional development, and peer coaching. Previously, Spaulding taught eighth-grade mathematics in a school district in southern New Hampshire. She holds an M.S. degree in middle school science from Simmons College and a B.S. in

About the Contributors, cont'd.

middle school mathematics and science education from Lesley College (now Lesley University). The Commonwealth of Massachusetts named Spaulding the state's Christa McAuliffe fellow for 2001.

Barbara Mitchell is a fifth-grade science teacher and curriculum coordinator at the Armstrong School, Westborough, Massachusetts, where she has piloted and implemented standards-based, hands-on math and science curricula. Mitchell began her career designing and developing a K-6 science lab at Happy Valley School, Lafayette, California, and was program associate and project coordinator for PALMS (Partnerships Advancing the Learning of Mathematics and Science) at EcoTarium, an environmental museum in Worcester, Massachusetts. Mitchell holds an M.S. from Clark University in professional communication and a B.S. from Castleton State College in elementary education. A frequent professional development and seminar facilitator, she is active in MAST (Massachusetts Association of Science Teachers) and other professional associations.

Joanne Aguiar has taught first grade for the past 13 years at the Laurel Lake School in Fall River, Massachusetts, an urban school serving students from various ethnic and economic backgrounds. Her professional development in science, math, and technology has included long-term involvement with the University of Massachusetts Dartmouth Buzzards Bay Rim Project, which led to visits at the Woods Hole Oceanographic Institution and research trips to Nantucket and Cuttyhunk Islands. Aguiar also attended the Next Steps Institute in Seattle, Washington, and a NEW Urban workshop at NASA's Goddard Space Flight Center. Through the University of Massachusetts/Dartmouth-Fall River Peer Coaching Collaborative Project, Aguiar assists and encourages co-workers to use hands-on science kits in the classroom. She enjoys nurturing young children's curiosity for learning.

Janet Smithers is a fourth-grade teacher in Harwich, Massachusetts. Her 21 years of teaching experience include regular and special education. She enjoys teaching science to children because they easily absorb the content and process through discovery activities that are both engaging and educational. She finds that the best way for fourth-grade students to learn scientific concepts and develop strong thinking processes is through their own observations and hands-on investigations.

Paul Martenis has taught physics and physical science for eight years in the Boston area, and currently teaches at Newton North High School, Newton, Massachusetts. He also worked on the computer staff at the Harvard-Smithsonian Center for Astrophysics for seven years. Martenis holds a master's degree in education from Harvard University and a bachelor's degree in astronomy and physics from Haverford College.

Interviewers

Ingrid Allardi is an assistant principal at the Harry Lee Cole Elementary School in Boxford, Massachusetts, where she works with teachers to develop grade-appropriate science curricula. Previously, she taught first grade for six years, and helped plan and create professional development programs in math and science for the Annenberg/CPB Channel. Allardi holds an M.A. in child study from Tufts University and a B.A. in psychology from Smith College. She has a special interest in educational administration and educating children with special needs.

Joyce Gleason has been a science educator for over 30 years and is currently the director of outreach for the Annenberg/CPB Channel at the Harvard-Smithsonian Center for Astrophysics. She has been a high school teacher, K-12 coordinator, staff developer in two urban districts, educator of student teachers (undergraduate and graduate), and independent consultant. She is a past president of the Massachusetts Association of Science Teachers and currently serves as district director for the National Science Teachers Association. She was named Massachusetts Science Educator of the Year in 2000, and was program coordinator for the National Science Teachers Association national convention in 1999.

Judith Peritz has been a curriculum developer with the science education department of the Harvard-Smithsonian Center for Astrophysics for the past 10 years. She also spent 10 years in classrooms as a pre-K/elementary school teacher, and is actively involved in after-school math and science tutoring. Peritz holds an M.Ed from Boston University and a B.S. in education from Case Western Reserve University.

Instructional Materials Appearing in the Workshop

Full Option Science System (FOSS)

(Grades K-6)

"Magnetism and Electricity" Module (Grades 3-4)

FOSS K-6 is a carefully planned and coordinated elementary science curriculum comprised of 27 modules. There are five modules at the kindergarten level, six for grades 1 and 2, eight for grades 3 and 4, and eight for grades 5 and 6. The modules are organized under four strands: Life Science, Physical Science, Earth Science, and Scientific Reasoning and Technology. The modular design of the program provides versatility so that FOSS can be used in many different school settings and its advanced assessment system provides complete information about student learning.

FOSS and FOSSweb are developed at the Lawrence Hall of Science, University of California, Berkeley, copyrighted by The Regents of the University of California, and published by Delta Education, Inc. For more information on the FOSS K-6 Program or the FOSS Middle School Program contact:

FOSS, Lawrence Hall of Science, University of California, Berkeley, CA 94720

phone: 510-642-8941; Web site: www.fossweb.com or

Delta Education, Inc.

phone: 800-258-1302

Insights: An Elementary Hands-On Inquiry Science Curriculum

(Grades K-8)

"Balls and Ramps" Module (Grades K-1)

Insights is designed to meet the needs of all children in grades K-6 while specifically addressing urban students. It is a core curriculum of 17 six- to eight-week modules in life, physical, and Earth sciences. The curriculum and accompanying materials were developed by science curriculum specialists from Education Development Center, Inc. (EDC) and elementary school teachers from several urban districts. They are designed to develop children's understanding of key science concepts, improve students' abilities to think creatively and critically, encourage problem solving through experiences in the natural environment, foster positive attitudes about science, bridge science concepts to current social and environmental events, and integrate science with the rest of the curriculum, particularly with language arts and mathematics.

Module topics are based on children's experiences and interests, basic science phenomena, and concepts appropriate for each age level with potential for hands-on exploration. Modules can be taught independently to supplement existing curricula, but are conceptually linked to help lead students to a broader understanding of themselves and the world around them.

Published by Kendall/Hunt Publishing. For more information, call 800-542-6657.

Web site: www.edc.org/cse/imd/insights3.html

Instructional Materials Appearing in the Workshop, cont'd.

Science and Technology for Children™ (STC)

(Grades K-6)

"Motion and Design" Unit (Grades 3-5)

Science and Technology for Children (STC) is a hands-on science program for children in Grades 1 through 6. The program has 24 units, four for each grade level, designed to provide students with stimulating experiences in the life, Earth, and physical sciences and technology while simultaneously developing their critical-thinking and problem-solving skills.

The STC units give children the opportunity to learn age-appropriate concepts and skills and to acquire scientific attitudes and habits of mind. In the primary grades, children begin their study of science by observing, measuring, and identifying properties. Then they move through a progression of experiences that culminate in Grade 6 with the design of controlled experiments. The units' "Focus-Explore-Reflect-Apply" learning cycle is based on research findings that knowledge is actively constructed by each learner and that children learn science best in a hands-on experimental environment where they can make their own discoveries.

The STC curriculum was developed by the National Science Resources Center (NSRC), a nonprofit organization operated jointly by the Smithsonian Institution and the National Academies. STC is published by Carolina Biological Supply Company and copyrighted by the National Academy of Sciences.

Web site: www.si.edu/nsrc/pubs/stc/stcmats.htm

Event-Based Science (EBS)

(Grades 6-9)

"Asteroid!" Module (Grades 6-9)

Event-Based Science is a new way to teach Earth, life, and physical science at the middle school level. EBS modules aim to increase science achievement by establishing relevance, a need-to-know, and a want-to-know. Videotaped television news coverage establishes the relevance; a real-world task creates the need-to-know; and engaging interviews, lively narrative, and team involvement lead to a want-to-know.

The series has 18 modules designed to last four to six weeks, each focusing on different themes and concepts across the domains of Earth, life, and physical sciences. The modules can be sequenced over all middle school grade levels and combined with other instructional materials in order to build a comprehensive middle school science program.

Event-Based Science was developed by teachers and staff from the Montgomery County (Maryland) Public Schools, and is published by Dale Seymour Publications. The EBS Project is supported by grants from the National Science Foundation and the National Aeronautics and Space Administration.

Web site: www.eventbasedscience.com

Physics: Principles With Applications

Textbook used for Workshop 8, by Douglas C. Giancoli, fifth edition, Prentice Hall, 1997.

Standards

National Science Education Standards (National Research Council)

K-4 Standards:

http://www.nap.edu/readingroom/books/nses/html/6c.html#ps

An object's motion can be described by tracing and measuring its position over time.

The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull.

— *Content Standards: K-4: Physical Science: Position and Motion of Objects*

Magnets attract and repel each other and certain kinds of other materials.

— *Content Standards: K-4: Physical Science: Light, Heat, Electricity, and Magnetism*

5-8 Standards:

http://www.nap.edu/readingroom/books/nses/html/6d.html#ps

The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

An object that is not being subjected to a force will continue to move at a constant speed and in a straight line.

If more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

— *Content Standards: 5-8: Physical Science: Motions and Forces*

9-12 Standards:

http://www.nap.edu/readingroom/books/nses/html/6e.html#ps

Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship $F = ma$, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them.

The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them.

Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules.

— *Content Standards: 9-12: Physical Science: Motions and Forces*

Standards, cont'd.

American Association for the Advancement of Science (AAAS) Project 2061 Benchmarks

http://www.project2061.org/tools/benchol/bolframe.htm

By the end of the second grade, students should know that:

Things move in many different ways, such as straight, zigzag, round and round, back and forth, and fast and slow.

The way to change how something is moving is to give it a push or a pull.

— The Physical Setting: 4F Motion: K-2

Things near the Earth fall to the ground unless something holds them up.

Magnets can be used to make some things move without being touched.

— The Physical Setting: 4G Forces of Nature: K-2

By the end of the fifth grade, students should know that:

Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be. The more massive an object is, the less effect a given force will have.

How fast things move differs greatly. Some things are so slow that their journey takes a long time; others move too fast for people to even see them.

— The Physical Setting: 4F Motion: 3-5

The Earth's gravity pulls any object toward it without touching it.

Without touching them, a magnet pulls on all things made of iron and either pushes or pulls on other magnets.

Without touching them, material that has been electrically charged pulls on all other materials and may either push or pull other charged materials.

— The Physical Setting: 4G Forces of Nature: 3-5

By the end of the eighth grade, students should know that:

An unbalanced force acting on an object changes its speed or direction of motion, or both. If the force acts toward a single center, the object's path may curve into an orbit around the center.

— The Physical Setting: 4F Motion: 6-8

Every object exerts gravitational force on every other object. The force depends on how much mass the objects have and on how far apart they are. The force is hard to detect unless at least one of the objects has a lot of mass.

— The Physical Setting: 4G Forces of Nature: 6-8

Standards, cont'd.

By the end of the twelfth grade, students should know that:

The change in motion of an object is proportional to the applied force and inversely proportional to the mass.

Whenever one thing exerts a force on another, an equal amount of force is exerted back on it.

— The Physical Setting: 4F Motion: 9-12

Gravitational force is an attraction between masses. The strength of the force is proportional to the masses and weakens rapidly with increasing distance between them.

Electromagnetic forces acting within and between atoms are vastly stronger than the gravitational forces acting between the atoms. At the atomic level, electric forces between oppositely charged electrons and protons hold atoms and molecules together and thus are involved in all chemical reactions. On a larger scale, these forces hold solid and liquid materials together and act between objects when they are in contact, as in sticking or sliding friction.

There are two kinds of charges, positive and negative. Like charges repel one another, opposite charges attract. In materials, there are almost exactly equal proportions of positive and negative charges, making the materials as a whole electrically neutral. Negative charges, being associated with electrons, are far more mobile in materials than positive charges are. A very small excess or deficit of negative charges in a material produces noticeable electric forces.

— The Physical Setting: 4G Forces of Nature: 9-12

Workshop 1.
Making an Impact

What would happen if an asteroid were to hit the surface of the Earth? How large a crater would the impact create? In this workshop, the ideas of force and motion are introduced, as seventh-grade students drop balls to simulate asteroid impacts. By varying a ball's mass, the height from which it is dropped, or the material being struck, the students explore what factors affect the size of the crater. They also learn about data collection and the proper use of measurement units.

On-Site Activities and Timeline

Getting Ready

30 minutes

How Well Do You Understand Force and Motion?

Below are 10 questions related to force and motion. Answer them as best you can. Do not panic! This is not a test. At the final workshop you will be able to see if any of your ideas about force and motion have changed.

Site Leaders: Please collect participants' questionnaires and bring them to Workshop 8.

____ ________________________

Name Date

Force and Motion Questionnaire

Please put the letter of your choice in the space provided next to the question.

____ 1. You are given two balls. One is twice as big as the other (twice the diameter). What can you say about the two balls?

a. The larger one has four times the surface area.

b. The larger one has eight times the weight.

c. The larger one has twice the volume.

d. Can't answer without knowing what they are made of.

____ 2. You are given two balls made of the same material. One is twice as big as the other (twice the diameter). What can you say about the two balls?

a. The larger one has twice the surface area.

b. The larger one has eight times the weight.

c. The larger one has four times the volume.

d. None of the above would be correct.

Base your answers to Questions 3 through 6 on the choices a through d on the next page. The graphs represent the position of a moving car after equal time intervals. The cars are moving from left to right, and each travels for the same amount of time.

____ 3. Which car travels the greatest distance?

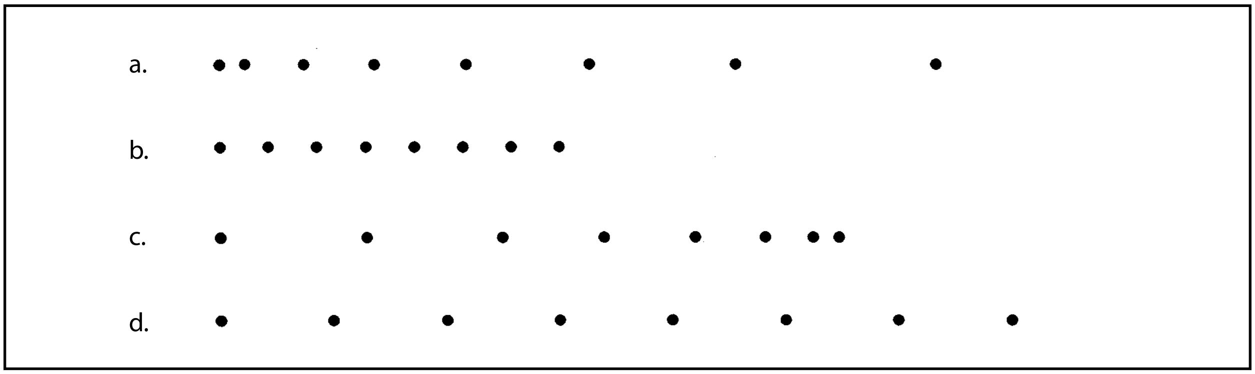
____ 4. Which car is slowing down?

____ 5. In which car would a speedometer read the highest?

____ 6. Which car is moving at the slowest constant speed?

Force and Motion Questionnaire, p. 2

____
Name



___ 7. If a ball is dropped from the window of a building to the ground,

a. it speeds up because of the downward force of the air pushing it.

b. it falls because it is natural for objects to rest on the Earth.

c. it speeds up because the gravity gets stronger as the ball gets closer to the ground.

d. it falls at a constant speed.

e. it speeds up because of the constant force of gravity.

___ 8. While you are driving on the highway, a bug collides with the windshield of your car. What can you say about the forces involved in the collision?

a. The windshield exerts a greater force on the bug than the bug exerts on the windshield.

b. The bug exerts a greater force on the windshield than the windshield exerts on the bug.

c. The forces of the bug on the windshield and the windshield on the bug are the same.

___ 9. A small car is used to tow a broken-down truck to the service station. What can you say about the force provided in this situation?

a. The small car exerts a greater force on the truck than the truck exerts on the car.

b. The truck exerts a greater force on the small car than the car exerts on the truck.

c. The forces of the car on the truck and the truck on the car are equal.

___ 10. Two balls of equal size are rolled down a ramp. One ball is twice as heavy as the other. What can you say about the motion of the two balls?

a. Both will reach the end of the ramp with about the same speed.

b. The heavier ball will reach the higher speed.

c. The lighter ball will reach the higher speed.

Force and motion questionnaires such as this are based on ideas taken from Physics Education Research, especially the "Force Concept Inventory," originally published by Hestenes et al. in *The Physics Teacher* (March 1992).

On-Site Activities and Timeline, cont'd.

A Force Is a Force, of Course, of Course?

Many scientific terms are also used in our everyday language. When scientists use a term it has a precise meaning, but this is not always true in casual conversation.

1. Please read the following example:

   "The PRESSURE exerted on the candidate by the polls will FORCE her to change her POSITION after she considers the GRAVITY of the situation."

2. Working alone, make a list of scientific terms that are also used in our everyday language. Try to list terms that you might use to describe how and why objects move.

3. Share your list with a partner. Do you agree on both the scientific and everyday meaning?

If you do not agree on the scientific meaning of the terms you are sharing, you are not alone. We hope that by the end of the workshops many of these key ideas will be clearer to you.

Watch the Workshop Video

60 minutes

As you watch the video, look for the "10-Cent Experiment." You may want to try it yourself at home. Instructions can be found on page 22.

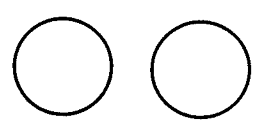
Going Further

30 minutes

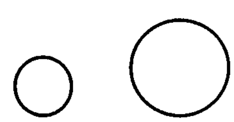
Mass, Weight, and Volume

After watching the video, discuss the following questions with a partner, or in a small group:

1. These two balls have the same volume, which means they take up the same amount of space. Do the balls have the same mass? How could you find out if your answer is right?

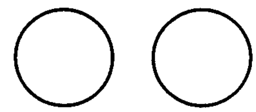


2. These two balls have different volumes. Do they have the same mass? How could you find out if your answer is right?

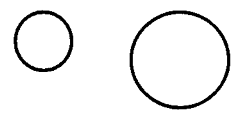


On-Site Activities and Timeline, cont'd.

3. These two balls have the same mass. Do they have the same weight? How could you find out if your answer is right?



4. These two balls have the same mass. Do they have the same weight? How could you find out if your answer is right?



5. You have two balls with the same volume, but one is made of steel and one is made of plastic. If you drop them from the same height, which ball will be traveling faster when it hits the sand? Which one would make the larger crater? Why do you think this is true?

6. Now, you have two balls with the same volume *and* the same mass. One is dropped from three times the height of the other. Which ball will be traveling faster when it hits the sand? Which one would make the larger crater? Why do you think this is true?

Make Your Own Spring Scale!

Materials:

A paper cup

A rubber band

Small objects for weighing

Instructions:

1. Make a small hole near the lip of the paper cup and slip the rubber band through the hole. Loop the rubber band through itself so that the cup hangs from it.
2. Put an object in the cup and measure how much the rubber band stretches.
3. Replace the first object with a different object and again measure the stretch. Observe what happens to the rubber band when you increase the weight.

Question:

If you took your cup scale to the Moon, would it stretch more or less than on Earth?

For Next Time

Homework Assignment

How Fast Is It Going?

1. In your journal, make a list of ways that you could determine the speed of a car as you watch it drive down the street. You may wish to divide your list into two columns labeled:

   a. Real, practical ways that should work; and

   b. Whimsical, impractical ways that would work but might be hard to do.

   Be prepared to discuss your ideas at the start of the next workshop.

2. Make a list of ways that you could stop a car that is in motion. Again, think about practical and impractical ways. Be prepared to discuss your ideas at the start of the next workshop.

The 10-Cent Experiment

Materials:

A marble

A muffin baking paper or a coffee filter

Instructions:

1. Drop the muffin paper (or filter) and the small ball side by side, from the same height.
2. Next, crumple the muffin paper into a ball and repeat the drop.

Questions:

What was the difference in the two drops?

Why?

Workshop 2.
Drag Races

Forces can help put objects into motion and can also bring moving objects to a stop. In this workshop, fifth-grade students explore the physics of motion using plastic cars with strings and washers attached to provide a pulling force. The students test the speed of the vehicles and explain what forces bring the vehicles to a stop, as the cars collide with and displace barriers at the end of their run. Finally, the students discuss their findings to help solidify their understanding of the effect of forces on motion.

On-Site Activities and Timeline

Getting Ready

30 minutes

Share What You Learned

For homework last time, you made a list of practical and impractical ways of measuring the speed of a car passing on the street. You also listed ways of stopping a car that is in motion. Take some time to discuss your ideas with your partner or group.

A Penny for Your Thoughts on the 10-Cent Experiment

In the video for Workshop 1, you saw an experiment with a marble and muffin paper. Perhaps you even tried it yourself. When the effects of air resistance were reduced, both objects fell at almost the same rate. Make a list of other ways to make both objects fall the same way when they are dropped. Share your ideas with the other participants.

Oil Drops and a Car's Motion

1. Suppose your car had a leaky oil pan that leaked one drop of oil on the road every second. Explain how the drops of oil could help you determine something about the motion of the car.

2. Now, work with a partner to discuss the following pictures of oil dripped on the road from a leaky car. The drops leak out of the car once every second. For each of the pictures below, describe what kind of motion the car is exhibiting, and how you know this.

a. 

b. 

c. 

d. 

On-Site Activities and Timeline, cont'd.

Watch the Workshop Video

60 minutes

As you watch the video, look for the "10-Cent Experiment." You may want to try it yourself at home. Instructions can be found on page 27.

Going Further

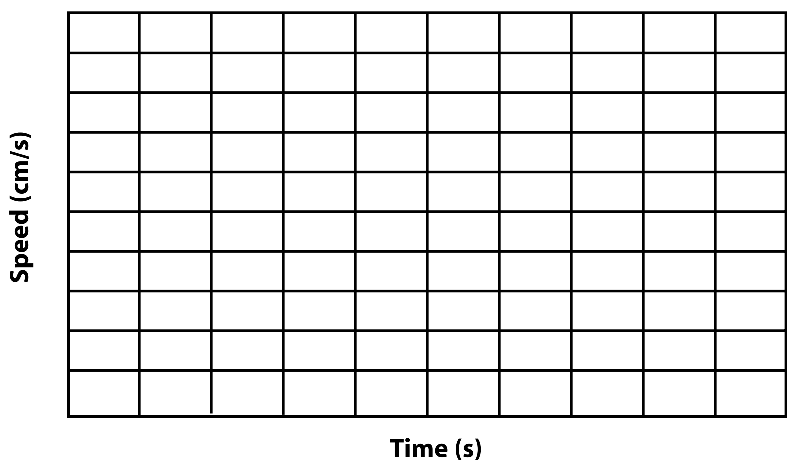
30 minutes

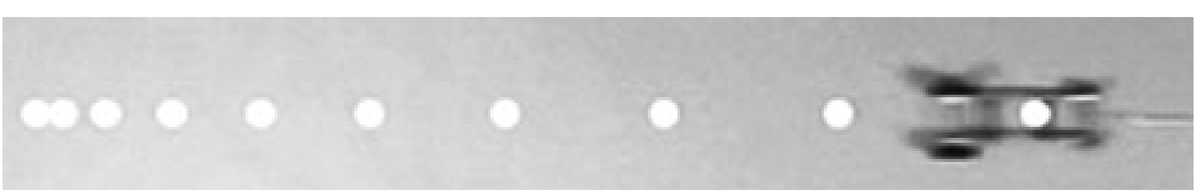
Plotting Motion

Below is a picture of a car's motion, with dots representing its position after time intervals of 1/5 of a second. We have also provided a data table, giving the car's speed in centimeters per second at different times during the run. Next to the table is a blank graph for you to complete.

1. Put a dot on your graph to represent each speed reading in the table.
2. Draw a smooth line through your data points.
3. Describe in words what the graph tells you about the motion of the car.

Speed	Time
(cm/s)	(s)
0	0
20	0.2
40	0.4
60	0.6
80	0.8
100	1.0
120	1.2
140	1.4
160	1.6
180	1.8

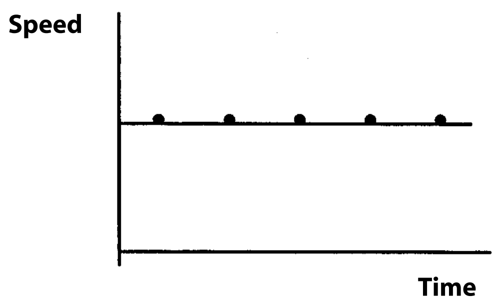


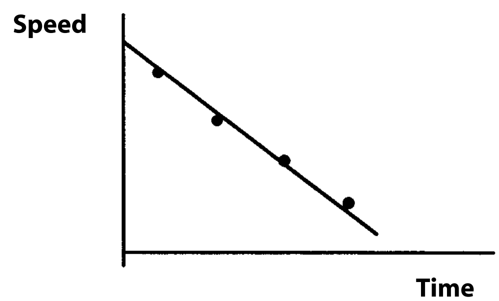


On-Site Activities and Timeline, cont'd.

Interpreting Motion Data

Examine the two graphs shown below. Discuss with a partner what you think they tell you about the motion of the car.

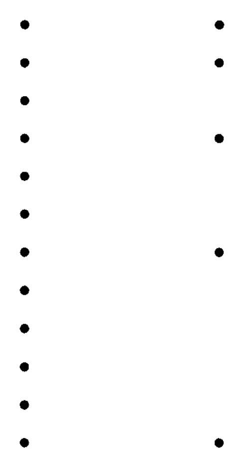




Which Is the Falling Ball?

Shown to the right are two pictures of the way a falling ball might appear if photographed during each second of fall. One of them is correct and the other is not.

1. Discuss with your partner what you think is different about the motion exhibited in each of the two pictures.
2. Describe the speed of the ball in each picture.
3. Which picture do you think is correct? Why?



For Next Time

Homework Assignment

Force, Motion, and Auto Safety

1. Use the Internet or other references to find information on how automobile safety devices help prevent injuries and fatalities in crashes.
2. In your journal, write responses to the following. Be prepared to discuss your ideas at the next workshop.

   a. Based on what you know about force and motion, explain the science behind why seatbelts and airbags save lives.

   b. When a car hits a barrier, how does the speed of the car determine the barrier's movement?
3. As a passenger, would you rather have a barrier that moves when you hit it, or a barrier that does not move? Explain why.

The 10-Cent Experiment

Materials:

Two raw eggs

A container of sand (depth of at least 6 inches)

A tile or other hard, flat surface

Instructions:

1. Drop the first egg onto the hard surface from a height of about 5 feet.
2. Drop the second egg from the same height onto the sand.

Questions:

Was there any difference in what happened to the egg?

Why or why not?

Notes

Workshop 3.

When Rubber Meets the Road

A rubber band twisted around the axle of a plastic car provides the force that moves the car forward. In this workshop, fifth-grade students continue their exploration of force and motion by recording and comparing the distance a vehicle travels under various conditions. Students predict the distance the car will travel by counting the number of twists in the rubber band, and observe the car's speed as it rolls across the floor. When the force of the rubber band stops acting, the force of friction slows the car to a stop.

On-Site Activities and Timeline

Getting Ready

30 minutes

Share What You Learned

As homework last time, you were asked to consider how airbags and seat belts save lives. Discuss your answers with the group.

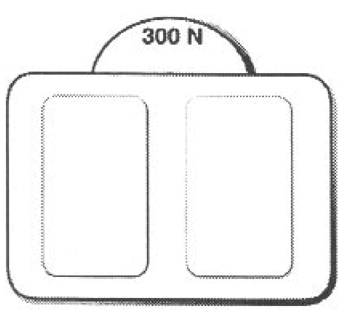
A Penny for Your Thoughts on the 10-Cent Experiment

In the video for Workshop 2, you saw an experiment in which two eggs were dropped. One egg fell on sand, the other on a hard surface. Perhaps you even tried it yourself. Make a list of several other ways to keep a dropped egg from breaking. Share your ideas with the other participants.

Does Our Weight Change in a Moving Elevator?

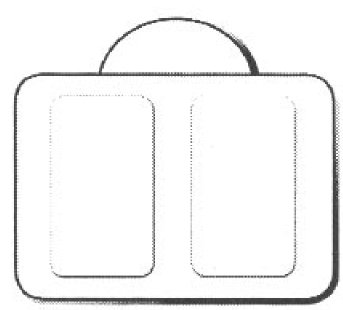
You may have noticed that when you ride in an elevator, there are times when you feel heavier or lighter than your normal weight due to the elevator's motion. (Have you ever jumped in an elevator just as it starts to move or is coming to a stop?) Now, imagine you are standing in the elevator on a bathroom scale. The first picture below shows the scale, seen from above, when the elevator is at rest. You can see that the scale reads 300 N. (N, a Newton, is a unit of force in the metric system. One Newton equals about 0.45 pounds, so a 300-N person weighs 135 pounds.)

With a partner, or in a small group, consider the following elevator situations. For each, draw an arrow on the bathroom scale to indicate what it would read. Don't worry about the *actual* numerical reading on the scale, but simply think about whether the scale would read higher, lower, or the same as it reads when the elevator is standing still. Explain your reasoning.



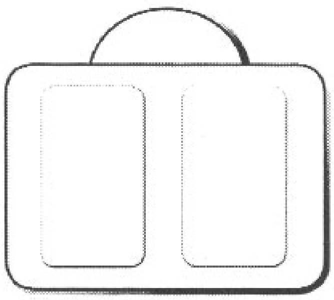
Elevator at Rest

Elevator Starting Upwards



Elevator Moving Up Between Floors

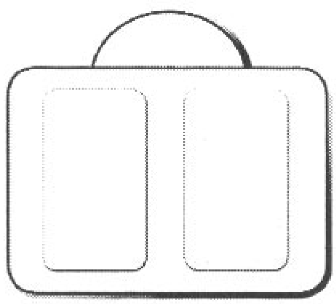
On-Site Activities and Timeline, cont'd.



Elevator Slowing Down
Preparing To Stop

Elevator Starting
Downwards

Elevator Moving Down
Between Floors



Elevator Slowing to a Stop

Elevator at Rest on the
Bottom Floor

To check your answers, go to the *Science in Focus: Force and Motion* Web site at:

http://www.learner.org/channel/workshops/force

Watch the Workshop Video

60 minutes

As you watch the video, look for the "10-Cent Experiment." You may want to try it yourself at home. Instructions can be found on page 33.

On-Site Activities and Timeline, cont'd.

Going Further

30 minutes

Reading the Speedometer

Materials:

Graph paper

Instructions:

In this exercise, you will have the opportunity to review what you have learned about motion and the ways to represent it. You will be describing motion in three different ways. In Activity A you will plot a graph, in Activity B you will draw some dots, and in Activity C you will write a story.

Complete each activity using the speedometer readings listed in the table below, all given in miles per hour (mph). Assume each of these readings was made after an equal interval of time. You may decide the length of the interval (i.e., one second, one minute, etc.).

Data are in mph

Speedometer Reading	Activity A Graph	Activity B Dots	Activity C Story
Reading 1	0	20	30
Reading 2	5	15	0
Reading 3	10	10	15
Reading 4	5	5	70
Reading 5	0	0	50

1. **Activity A:** Using a piece of graph paper and the five speedometer readings listed for Activity A, plot a graph of the object's motion. What type of object might move in this pattern?
2. **Activity B:** Using the five speedometer readings listed for Activity B, draw dots spaced in such a way as to indicate the motion of the object. What type of object might move at these speeds?
3. **Activity C:** Using a separate sheet of paper and the five speedometer readings listed for Activity C, make up a story about an object that might move along with the five speeds shown.

For Next Time

Homework Assignment

What Would the World Be Like Without Friction?

Congressman Notsosmart is testifying before a Senate Subcommittee about the nation's energy concerns. He explains that our nation has a dwindling supply of natural resources, and that we will put our future at risk if we do not find a way to curb energy use in the near future. The Congressman proposes that to reduce energy demands, the nation should do away with friction.

Write a letter to the Congressman explaining why you feel that this is a bad idea. Support your letter with examples that explain why we do not want to abolish friction.

Make good arguments to support your position by explaining to the Congressman what it would be like to live in a frictionless world. Be sure you back up your claims with appropriate examples. Be creative! Have fun!

The 10-Cent Experiment

Materials:

A toy car

A smooth board

Flat objects with different surface textures, such as:

A stopwatch

- Sandpaper
- A dish towel

Instructions:

1. Create a ramp by propping the board against a wall or firm support.
2. Roll the car down the ramp and record with a stopwatch how long it takes to reach the bottom.
3. Repeat, covering the ramps with different surface textures.

Questions:

Did the cars reach the bottom of the ramp at different times?

Why or why not?

Notes

Workshop 4.
On a Roll

The force of gravity makes a ball roll when it is placed on an incline. In this workshop, first-grade students roll balls of different sizes, masses, and materials down ramps of varying heights, comparing their speeds. The students then experiment by replacing the ramp with a cardboard tube, and try to determine how the tube must be oriented to allow the ball to roll, much as it rolled down the ramp.

On-Site Activities and Timeline

Getting Ready

30 minutes

Is Friction a Good or Bad Thing?

1. Trade your Congressman Notsosmart letter with a partner. Read your partner's letter and discuss one thing you really liked about it, and one thing (if anything) with which you disagree. Share your results with the rest of the group.

2. With your partner, make two lists:

   a. A list of situations in which you would like to have lots of friction, and why.

   b. A list of situations in which you would like to have as little friction as possible, and why.

   Share your results with the rest of the group.

A Penny for Your Thoughts on the 10-Cent Experiment

In the video for Workshop 3, you saw an experiment in which the same car was rolled down a ramp over three different surfaces. Perhaps you even tried it yourself. What other materials could you have placed on the ramp? Will the car always roll down the ramp? How could you change the experiment to make the car roll faster or slower? If you turned the car over on its roof, would it slide down the ramp? Share your ideas with the other participants.

Watch the Workshop Video

60 minutes

As you watch the video, look for the "10-Cent Experiment." You may want to try it yourself at home. Instructions can be found on page 38.

On-Site Activities and Timeline, cont'd.

Going Further

30 minutes

Designing a Better Roller Coaster

Roller coasters are great places to experience force. However, a roller coaster that is fun for a small child might be rather boring for an adult, while an adult-style roller coaster would be much too scary for a child. Imagine going to work each day just to design roller coasters. There are people whose job it is to do just that. Today it is your task.

1. Work with a partner to design:

    a. A roller coaster for first-grade students

    b. A roller coaster for adults

    Describe the hills, loops, twists, and turns you plan to include in each roller coaster, and draw a sketch of how it will appear from the side.

2. Present your design to the whole group. What things should be the same about both roller coasters to create the desired "thrill effect"? What things should be different?

Try It on the Web!

Now that you've designed your own roller coaster, try doing it again online at http://www.learner.org/exhibits/parkphysics/coaster/ where you will be able to test whether your roller coaster design is safe and fun.

For Next Time

Homework Assignment

Ramping Up

In your journal, make a list of all the places you can think of where ramps are used to move an object from one location to another. Write a response to the following questions:

1. When do you want a ramp that is inclined at a high angle? At a low angle?

2. Why does the angle of a playground slide change near the bottom?

3. When you drive up a mountain, the road winds around gradually in a "switchback." Why doesn't the road go straight up the side of the mountain like a ramp?

4. Ramps sometimes provide an alternative to stairs. If there were no elevator, would you choose the stairs or a ramp to go up to the second floor? What are the reasons for your choice? Would your answer change if you were going down?

For Next Time, cont'd.

The 10-Cent Experiment

Materials:

A smooth board

Three identically sized soup cans:

- A can of thick soup, such as split pea
- A can of broth
- An empty can (with the top and bottom removed)

Instructions:

1. Create a ramp by propping the board against a wall or firm support.
2. Roll each can down the ramp and observe its motion.

Questions:

Which can reaches the bottom first? Which reaches the bottom last?

Why?

Workshop 5.
Keep On Rolling

Roller coasters are filled with twists and turns, as changes in height and direction supply a variety of push and pull forces. In this workshop, first-grade students build on their prior experience with rolling objects. By designing and constructing their own roller coaster made from ramps, cardboard tubes, and flexible tubes, the students experiment with ways to get a marble from the top of a table into a bucket on the floor, some distance away.

On-Site Activities and Timeline

Getting Ready

30 minutes

Share What You Learned

For homework last time, you were asked to answer some questions about ramps. Take a few minutes to share your responses with the group or a partner.

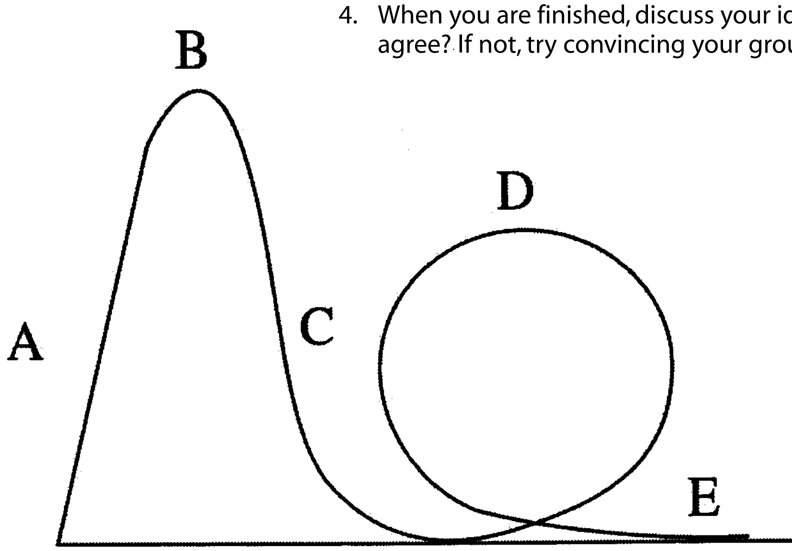
A Penny for Your Thoughts on the 10-Cent Experiment

In the video for Workshop 4, you saw an experiment involving three soup cans rolled down a ramp—one empty can, one with broth, the third with a thick soup. Perhaps you even tried it yourself. The empty can reached the bottom of the ramp last. What do you think would happen if you used two empty cans of different diameters? What would happen if you changed the surface of the ramp? If you allowed the three cans to continue to roll after reaching the bottom of the ramp, which would roll the greatest distance? Share your ideas with the other participants.

What Does It Feel Like To Ride on a Roller Coaster?

The picture below shows a roller coaster marked with points A, B, C, D, and E. Work with a partner and discuss the questions below.

1. Imagine you are riding in the roller coaster. What do you feel at each point?
2. At which point would you expect the highest speedometer reading? The lowest? Are there two or more points where you would expect the reading to be the same? Are there any points where you would expect the speedometer to read zero?
3. Draw an arrow at each point to indicate the direction of the force you feel.
4. When you are finished, discuss your ideas with the entire group. Do your ideas agree? If not, try convincing your group members of your point of view.



On-Site Activities and Timeline, cont'd.

Watch the Workshop Video

60 minutes

As you watch the video, look for the "10-Cent Experiment." You may want to try it yourself at home. Instructions can be found on page 43.

Going Further

30 minutes

Force and Motion in the Amusement Park

Work with your partner to come up with a list of your favorite amusement park rides. Do the following activities together.

1. Imagine yourself on these rides, as you did earlier with the roller coaster. Describe the forces you feel during the course of each ride. These forces may change or may remain constant depending on the rides you select.
2. Now imagine each ride has a speedometer that you can see. Describe where in the ride the speedometer would indicate the slowest speed, and where it would show the fastest speed. Is there a place where it would read zero?
3. Are there any relationships between each ride's speed and the force you feel? Describe any connections you see.

Try It Online!

Now that you've thought about some amusement park rides, go to some of the following Web pages where you will be able explore further:

http://www.learner.org/exhibits/parkphysics/carousel.html
http://www.learner.org/exhibits/parkphysics/bumpcars.html
http://www.learner.org/exhibits/parkphysics/freefall.html
http://www.learner.org/exhibits/parkphysics/pendulum.html

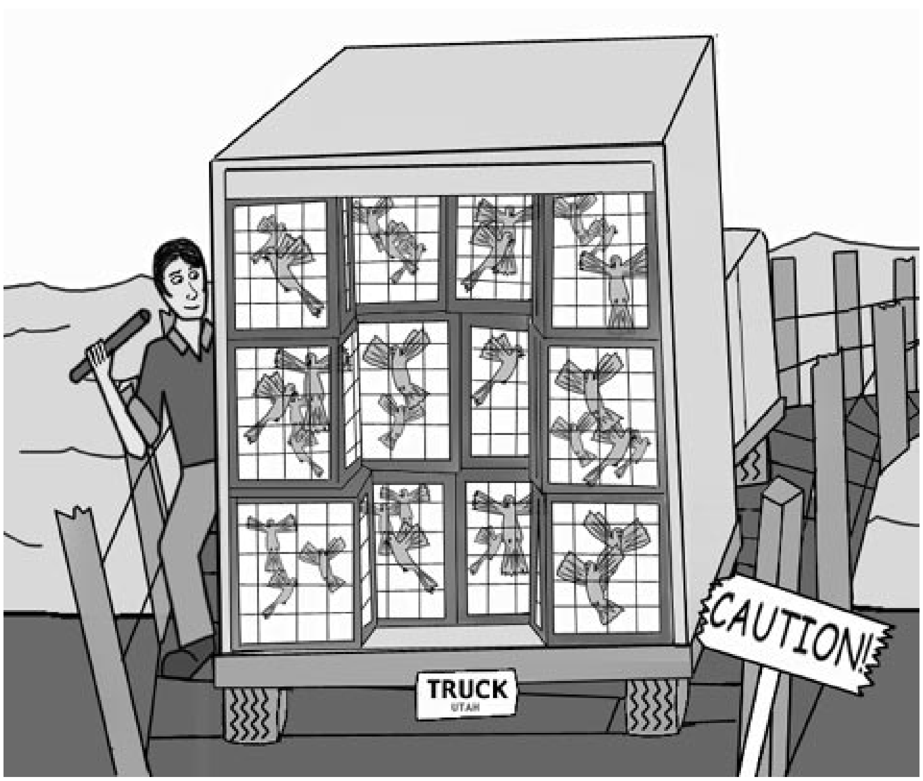
For Next Time

Homework Assignment

Canary Physics

Based on what you now know about forces, see if you can solve the following riddle. Be prepared to discuss your ideas with the group during your next session.

A man driving a truckload of canaries to a pet store comes to a bridge that is old and in bad condition. A warning sign tells the driver the weight limit the bridge can support. The bridge can support the weight of the truck and the driver, but not the added weight of the canary cargo. The driver, however, has studied force. He picks up a stick and bangs on the side of the truck until all the canaries start flying around in their cages. Then he quickly hops in the truck and starts to drive across the bridge. If all the canaries continue flying as he drives, does he make it across the bridge without it breaking?



To check your answer, go to the *Science in Focus: Force and Motion* Web site at:

http://www.learner.org/channel/workshops/force

For Next Time, cont'd.

The 10-Cent Experiment

Materials:

A smooth board

Two wooden toy building blocks, one twice as long as the other

Instructions:

1. Drop the two blocks together from the same height, and notice how they fall.
2. Now, create a steep ramp by propping the board against a wall or firm support.
3. Slide the two blocks down the ramp.

Questions:

Did the falling blocks behave the same as the blocks that slid?

Why or why not?

Notes

Workshop 6.
Force Against Force

Magnets stick to other magnets and to metal objects made of iron or steel. How much force is required to break the attraction between two magnets? In this workshop, fourth-grade students explore ways to balance the force of magnetism against the force of gravity. A magnet placed in a cup on one side of a pan-balance is stuck to a stationary magnet beneath the cup. When enough washers are placed on the opposite side of the balance, the magnets will separate. Graphical analysis shows some unexpected results.

On-Site Activities and Timeline

Getting Ready

30 minutes

Canary Physics Follow-Up

Your homework for Workshop 5 was to solve a canary physics problem. Now, discuss with your group some of your ideas about the truckload of canaries. Does the group believe that the bridge will break or hold together when the truck drives over?

A Penny for Your Thoughts on the 10-Cent Experiment

In the Workshop 5 video, you saw an experiment where two wooden blocks were first dropped, then slid down a ramp. One block had twice the mass of the other. Perhaps you tried the experiment to see how the sliding blocks behaved. What would happen if the ramp were much less steep? Share your ideas with the other participants.

Tug of War

Materials:

A non-carpeted floor

Two chairs, preferably with wheels

A rope or cord at least 4 to 6 meters long

Instructions:

1. From your group, select a person of very large mass and a person of very small mass. Have each sit in a chair facing the other, each holding one end of the rope. Move the chairs back so the two people are as far apart as possible, with the rope stretched tightly between them.
2. The two participants will now try each of the following challenges (move back to the original starting position before each trial):
   a. The high-mass person "reels in" the low-mass person by pulling the rope
   b. The low-mass person "reels in" the high-mass person
   c. Both "reel in" each other
3. After each activity, the people in the chairs should discuss what they felt during the activity, and those watching should describe the motion they observed.
4. Repeat the same experiment with two people of approximately equal mass and discuss your results.

Questions (discuss with a partner):

How does motion relate to mass?

How does motion relate to force?

On-Site Activities and Timeline, cont’d.

Watch the Workshop Video

60 minutes

As you watch the video, look for the “10-Cent Experiment.” You may want to try it yourself at home. Instructions can be found on page 49.

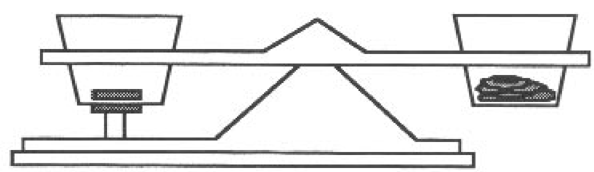
Going Further

30 minutes

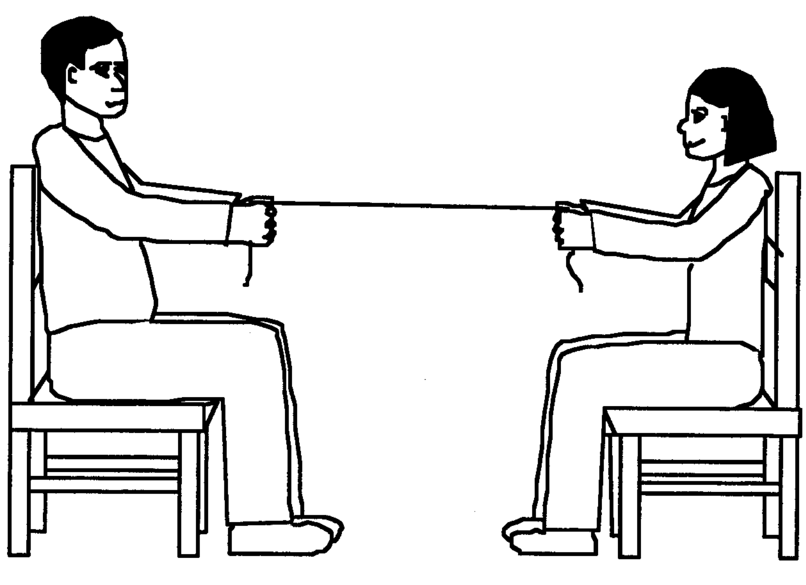
Can You Find All the Forces?

Work with a partner on the following activities and questions:

1. In the Workshop 6 video, students were separating magnets by using washers in a pan balance to provide a force. Below is a picture of a balance similar to the one in the video. Use arrows to represent all the places where force is being exerted.

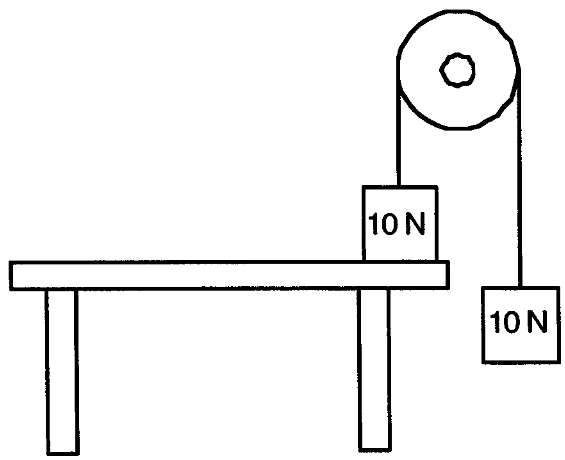


2. In the Workshop 6 Getting Ready, you participated in a makeshift tug-of-war while sitting in chairs, or watched some of your colleagues do so. Below is a picture of two people participating in this activity. Use arrows to represent each force being exerted.



On-Site Activities and Timeline, cont'd.

3. Below is a picture of two blocks attached to a string that passes over a pulley. The blocks have equal mass. One block is resting on the table and the other is hanging freely.

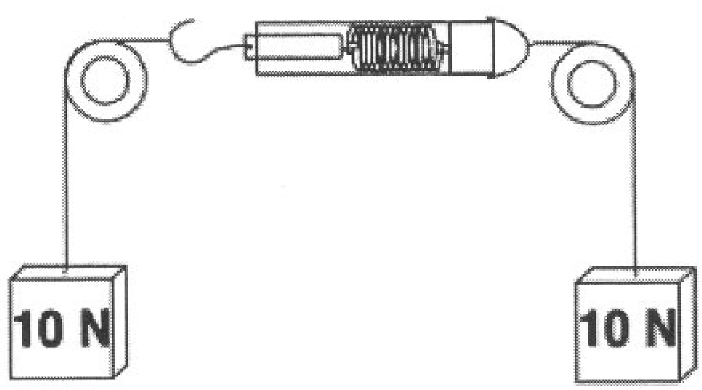


   a. Draw arrows to show each force being exerted.

   b. Explain what will happen if the table is removed.

   c. Be prepared to discuss your reasoning with the rest of the group.

4. Below is a picture of two blocks of equal mass attached by strings to a spring scale. The strings pass over two pulleys as shown. What do you expect the spring scale to read? Be prepared to discuss your reasoning with the rest of the group.



To check your answers, go to the *Science in Focus: Force and Motion* Web site at:

http://www.learner.org/channel/workshops/force

For Next Time

Homework Assignment

The Clipper Picker Upper

1. Find the strongest magnet you have in your house. Most likely you will find it on your refrigerator door! See how many paper clips the magnet can pick up end to end.
2. In your journal, write your thoughts about the following:
   a. Why does a paper clip behave like a magnet when it is attached to a real magnet?
   b. What do you think is happening to the paper clip to make it behave "magnetically"?

The 10-Cent Experiment

Materials:

Four small ring magnets

A pencil

Instructions:

1. Slide the pencil through the four ring magnets, then hold the pencil horizontally.
2. Now, tip the pencil and hold it vertically.
3. Note the behavior of the magnets.

Questions:

Did the magnets behave differently when the pencil was vertical?

Why?

Notes

Workshop 7.
The Lure of Magnetism

What is the difference between a permanent magnet and an electromagnet? In this workshop, fourth-grade students build an electromagnet by winding a wire around a rivet and attaching the ends to battery terminals. The students first predict how many washers they can pick up with the help of their electromagnet and then perform the experiment to test their predictions. After the number of washers is recorded and the results are discussed, the students engage in a group discussion about practical uses for electromagnets.

On-Site Activities and Timeline

Getting Ready

30 minutes

Share What You Learned

For homework, you used a string of paper clips to investigate the pick-up power of a magnet. Take a few minutes to discuss your observations with the group or a partner.

A Penny for Your Thoughts on the 10-Cent Experiment

In the Workshop 6 video, you saw an experiment involving four ring magnets on a pencil. Perhaps you even tried it. When the pencil was held horizontally, the four magnets were equally spaced, but when held vertically, the bottom magnets were closer together than the top ones. Write down how you think the results would change if we used three magnets rather than four. What would happen if we used five? What would happen if the experiment could be done on the Moon? Share your ideas with the other participants.

Building an Electromagnet

Materials:

A 1.5-volt battery

A 2-inch or longer nail

1 yard of thin insulated wire (remove any insulation from the ends)

A box of paper clips

Instructions:

Do this activity with a partner.

1. Wind the wire tightly around the nail so that you have 25 turns, leaving enough wire free at each end to connect it to the battery.
2. Connect one end of the wire to the top terminal of the battery (the positive [+] terminal) and one to the bottom of the battery (the negative [-] terminal).
3. See how many paper clips you can pick up with the nail and record the number in the table to the right.
4. Now add five more turns of wire and again see how many paper clips you can pick up. Again, record the number.
5. Repeat this process until you have 50 turns of wire around the nail.
6. Is there a relationship between the number of turns of wire and the number of paper clips your electromagnet can lift?

Number of turns	Number of paper clips
25	
30	
35	
40	
45	
50	

On-Site Activities and Timeline, cont'd.

Watch the Workshop Video

60 minutes

As you watch the video, look for the "10-Cent Experiment." You may want to try it yourself at home. Instructions can be found on page 55.

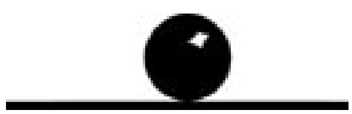
Going Further

30 minutes

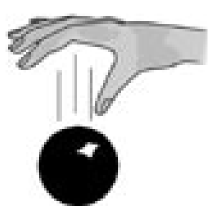
How Many Forces Can You Find?

During the past few sessions you have been learning how to use arrows to represent forces on objects. Working on your own or with a partner, draw arrows to represent the force acting on the ball in each situation below.

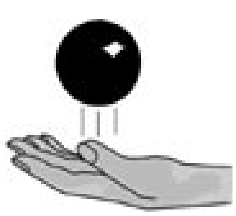
1. A ball sits on a table.



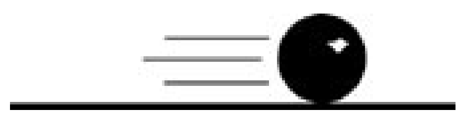
2. A ball is dropped.



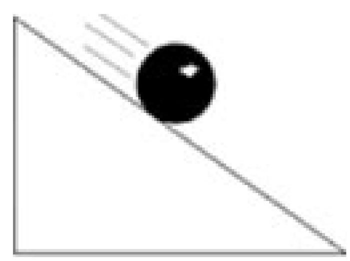
3. A ball is thrown up in the air.



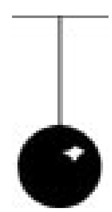
4. A ball rolls across a table.



5. A ball rolls down a ramp.



6. A ball hangs from a string.



To check your answers, go to the *Science in Focus: Force and Motion* Web site at:

http://www.learner.org/channel/workshops/force

For Next Time

Homework Assignment

Electromagnetism in the Real World

For this assignment, select any device that uses electromagnetism and design a poster to help others understand how it works. Your poster should fit on one piece of poster board and may include pictures, text, drawings of the device, or anything else that will help others to understand how it works.

At the start of the next workshop, you and your colleagues will hold a "poster session," and you will have the opportunity to share what you have learned. The poster should give enough detail so that even students in your class would understand how your device works.

Here are some examples of devices that use electromagnetism:

An MRI machine

An airport metal detector

A ground metal detector (treasure finder)

A credit card scanner

A junk yard scrap metal sorter

A telephone

A stereo speaker

A video tape player

A computer hard drive

A doorbell

Site Leaders: Remember to bring copies of participants' completed questionnaires from Workshop 1 to the next (final) workshop.

For Next Time, cont'd.

The 10-Cent Experiment

Materials:

Five identical rubber bands

Two paper clips

A ruler

A set of keys (or other object that can act as a weight)

Instructions:

1. Hang the keys from a paper clip on a single rubber band and measure the length of stretch of the band.
2. Connect two rubber bands chain-style (end-to-end), and hang the keys from the chain. Measure the length of stretch of the rubber bands.
3. Finally, hang the keys on two rubber bands placed side by side (so as to create a single, two-strand band). Again, measure the length of the stretch.

Questions:

How did the amount of stretch differ with the different arrangements of rubber bands?

Why?

Notes

Workshop 8.

Bend and Stretch

We all expect a spring to stretch or compress when a force is applied, but forces can even deform solid objects like the floor or the top of a table. In this workshop, students in a high school classroom explore ideas about tension and normal force. By applying a force to a spring and measuring the distance the spring is stretched, the students calculate the force constant or stretchiness of the spring. Lecture demonstrations using student volunteers help illustrate that even rigid objects bend when a force is applied.

On-Site Activities and Timeline

Getting Ready

30 minutes

Poster Session

For homework, you were asked to create a poster of a familiar device that uses electromagnetism. Present your poster to the group and discuss what you have learned.

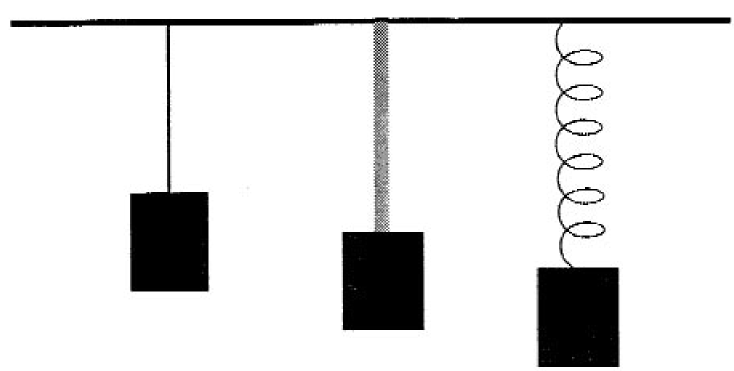
A Penny for Your Thoughts on the 10-Cent Experiment

In the video for Workshop 7, you saw an experiment in which the same set of keys was hung from three different arrangements of rubber bands. Perhaps you tried it on your own. The two rubber bands connected end-to-end stretched twice as much as the single band, whereas the two rubber bands together stretched only half as much as the single band. How can you explain this result? What would happen if you used three rubber bands? Share your ideas with the other participants.

Hanging Force

The diagram below shows three 1-kg masses hanging from supports. The first support is a string, the second is a rubber band, and the third is a spring.

Which support—string, rubber band, or a spring—provides the greatest force? Why did you select this as your answer? Write down your prediction and discuss your thoughts with the rest of the group.



On-Site Activities and Timeline, cont'd.

Watch the Workshop Video

60 minutes

As you watch the video, look for the "10-Cent Experiment." You may want to try it yourself at home. Instructions can be found on page 62.

On-Site Activities and Timeline, cont'd.

Going Further

30 minutes

How Well Do You Understand Force and Motion Now?

Site Leaders: After participants have completed the questionnaire below, please distribute their original Workshop 1 questionnaires for comparison. At the end of the workshop, please collect both sets of questionnaires and return them to the Annenberg/CPB Channel, c/o Harvard Smithsonian Center for Astrophysics, 60 Garden Street, M.S. 82, Cambridge, MA 02138.

Below are the 10 questions on force and motion that you answered before the first workshop. Again, please answer the questions as best you can. When you are finished, compare it with your original sheet, so you can see what you've learned!

Name ______________________ Date ______________

Force and Motion Questionnaire

Please put the letter of your choice in the space provided next to the question.

___ 1. You are given two balls. One is twice as big as the other (twice the diameter). What can you say about the two balls?

- a. The larger one has four times the surface area.
- b. The larger one has eight times the weight.
- c. The larger one has twice the volume.
- d. Can't answer without knowing what they are made of.

___ 2. You are given two balls made of the same material. One is twice as big as the other (twice the diameter). What can you say about the two balls?

- a. The larger one has twice the surface area.
- b. The larger one has eight times the weight.
- c. The larger one has four times the volume.
- d. None of the above would be correct.

Base your answers to Questions 3 through 6 on the choices a through d on the next page. The graphs represent the position of a moving car after equal time intervals. The cars are moving from left to right, and each travels for the same amount of time.

___ 3. Which car travels the greatest distance?

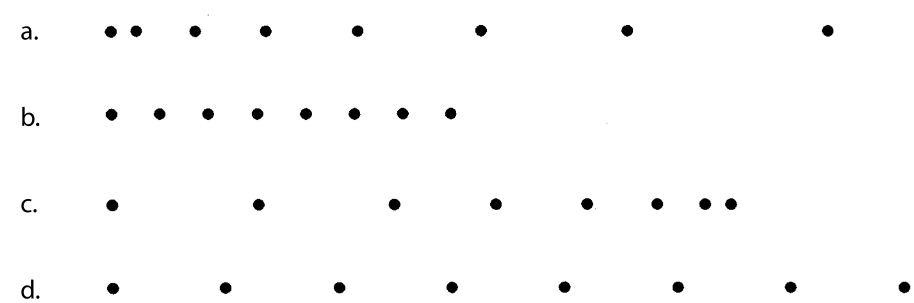
___ 4. Which car is slowing down?

___ 5. In which car would a speedometer read the highest?

___ 6. Which car is moving at the slowest constant speed?

Force and Motion Questionnaire, p. 2

Name



___ 7. If a ball is dropped from the window of a building to the ground,

a. it speeds up because of the downward force of the air pushing it.

b. it falls because it is natural for objects to rest on the Earth.

c. it speeds up because the gravity gets stronger as the ball gets closer to the ground.

d. it falls at a constant speed.

e. it speeds up because of the constant force of gravity.

___ 8. While you are driving on the highway, a bug collides with the windshield of your car. What can you say about the forces involved in the collision?

a. The windshield exerts a greater force on the bug than the bug exerts on the windshield.

b. The bug exerts a greater force on the windshield than the windshield exerts on the bug.

c. The forces of the bug on the windshield and the windshield on the bug are the same.

___ 9. A small car is used to tow a broken-down truck to the service station. What can you say about the force provided in this situation?

a. The small car exerts a greater force on the truck than the truck exerts on the car.

b. The truck exerts a greater force on the small car than the car exerts on the truck.

c. The forces of the car on the truck and the truck on the car are equal.

___ 10. Two balls of equal size are rolled down a ramp. One ball is twice as heavy as the other. What can you say about the motion of the two balls?

a. Both will reach the end of the ramp with about the same speed.

b. The heavier ball will reach the higher speed.

c. The lighter ball will reach the higher speed.

Force and motion questionnaires such as this are based on ideas taken from Physics Education Research, especially the "Force Concept Inventory," originally published by Hestenes et al. in *The Physics Teacher* (March 1992).

Optional Activities

The Bucket of Nails Fable

Bob and Joe, two construction workers on the roof of a building, are about to raise a bucket of nails from the ground by means of a rope passing over a pulley on the roof. The nails weigh more than Bob or Joe individually, but less than Bob and Joe together. However, the following unfortunate sequence of events happens:

1. While both Bob and Joe are holding the rope, they slip off the roof and fall to the ground, causing the bucket of nails to fly up in the air.
2. Just as they hit the ground, Bob lets go of the rope. The bucket of nails falls, dragging Joe up to the pulley, where he cracks his head against the pulley but gamely hangs on.
3. However, when the bucket hits the ground, the nails fall out, causing Joe to come plummeting back to the ground.
4. Having had enough of this ordeal, Joe lets go of the rope and remains on the ground, only to be hit on the head by the empty bucket.

Discuss with your partner what is providing the force in each of these four sequences.

The 10-Cent Experiment

Materials:

A coiled spring

A ball (of proportionate size, to rest on top of the spring)

Instructions:

1. Balance the ball on top of the spring.
2. Compress the spring by different amounts, with the ball on top. Release the spring and see how high the ball goes up.

Questions:

Is the spring pushing harder on the ball, or on the table?

Why?

Appendix

Video Credits

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Morse School, Cambridge, Massachusetts

Barbara Mitchell, Grade 5
Armstrong School, Westborough, Massachusetts

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Original Music
Alison Reid
Treble Cove Music

Animation/Graphic Design
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Graphic Design
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Associate Producers
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Production Assistants
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Instructional Materials
"Asteroid!," an Event-Based Science module, published by Dale Seymour Publications

"Motion and Design," a Science and Technology for Children unit, published by Carolina Biological Supply Company

"Balls and Ramps," an EDC, Insights module, published by Kendall/Hunt Publishing

"Magnetism and Electricity," a FOSS module, published by Delta Education, Inc.

Physics: Principles With Applications, by Douglas C. Giancoli. (Fifth edition, Prentice Hall, 1997).

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