

HEADJAM

Slinky® Science

Instructional Guide

Made Possible by


ConocoPhillips

Slinky® Science Teaching Guide

This teaching guide is designed to complement the 20-minute video, Slinky® Science.

Richard James, a mechanical engineer, was employed by Philadelphia's Cramp Shipyard in 1943 when he accidentally invented the Slinky®. At the time, he was trying to develop a spring to keep ship instruments steady at sea.

As James tested hundreds of springs of varying sizes, metals, and tensions, he piled the discards onto his desk. One day, an experimental torsion spring fell off the desk and "walked" down a pile of books, tumbling end over end onto the floor.

James was intrigued with the steel spring's antics and took it home for his children. Soon all the kids in the neighborhood wanted one too. His invention hadn't worked as an anti-vibration device for ships, so he decided to turn it into a toy.

In 1945, the first Slinky was demonstrated at Gimbels Department Store in Philadelphia. Within 90 minutes after the toy's performance, all 400 Slinkys on hand were sold.

James designed and engineered machines to transform 80 feet of wire into a two-and one-half-inch stack of 98 coils, and he and his wife, Betty, co-founded James Industries. Today the company continues to operate in Hollidaysburg, Pa., manufacturing some 3 million to 4 million Slinkys annually. Mrs. James, who came up with the name "Slinky" has been chief executive officer since 1960.

The first Slinkys were manufactured from an expensive, dark steel from Sweden. It wasn't long though before the Jameses switched to a more silver-looking steel; then in the '60s, a coating gave the spring an even more silvery appearance. Since late 1978, the Slinky also is made of the plastic, K-Resin® styrene-butadiene copolymer from Chevron Phillips Chemical Co.



"We decided to make Slinkys in plastic," explained Mrs. James, "because younger children tangled the metal ones too easily and had trouble holding onto them. With plastic, we can manufacture a larger diameter Slinky which is easier for small hands to manage, and we can produce it in bright colors that really appeal to children."

The Slinky's design has been changed only once since 1943, and that was in 1973 to make the ends blunt for safety reasons.

Through the years, the novelty of the Slinky has never faded, and it remains one of the most successful toys of all time. Since 1947, sales have topped more than 250 million. That's a Slinky for every resident of the United States.

Slinky® Tidbits

- Betty James, CEO of James Industries and widow of Slinky inventor Richard James, named the famous toy. She scanned the dictionary for ideas and knew she'd found the perfect name with "Slinky," which is Swedish and means stealthy, sleek, sinuous.
- Some very innovative uses have been found for the Slinky. It has been used in pecan-picking devices in Texas and Alabama; on lighting fixtures in Harrah's Casino in Las Vegas because of the unusual shadows it casts; and as table decorations, drapery holders, bird repellers, mail holders, therapeutic devices, wave motion coils, gutter protectors, and in numerous other ways. During the war in Vietnam, soldiers found that when draped over tree branches, the metal Slinky was an excellent makeshift radio antenna. Also, the Slinky sometimes is prescribed by physical therapists for coordination development.
- The amount of wire used since 1943 to make Slinkys could wrap around the Earth 126 times.
- Fifty years after its invention, the Slinky sells for only about twice the one dollar it originally cost.
- The Slinky has appeared in several movies, including *Ace Ventura: When Nature Calls*, *Demolition Man*, *Other People's Money*, and *Hairspray*, and the Slinky® Dog played in *Toy Story*.

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Slinky® Science Classroom Activities

In addition to being a terrific toy, the Slinky is an excellent device for demonstrating various properties of physics.

The Slinky, like all objects, tends to resist change in its motion. Because of this inertia, if placed at the top of stairs it stays at rest. At this point it has potential or stored energy. But once it is started down the stairs and gravity affects it, the potential energy is converted to the energy of motion or kinetic energy and the Slinky gracefully tumbles coil by coil down the stairs.

Physical properties of the Slinky determine how quickly it moves under the influence of gravity. Although its movement may look simple, from a scientific point of view the motion is quite complex.

Activity #1: Racing Slinkys

In this activity, inertia, gravity, potential energy, kinetic energy, and longitudinal waves are demonstrated when the Slinky “walks” down stairs or an incline.

1. Show the class two Slinkys of different sizes and ask which one they think will win a race down stairs or an incline. (Graduated stacks of books work well; also any board or table top with a non-slip surface will do. Slope surface so rise equals about 1 foot for every 4-foot length.)
2. Place both Slinkys on the top stair or top of a ramp. Ask why the Slinkys remain motionless. What will it take to get them in motion? (Newton’s first law of motion: A body at rest will remain at rest unless an external force acts upon it. A body in motion will remain in motion in a straight line at a steady speed unless an external force acts upon it.)
3. Grip a coil of each Slinky at the top and flip it over toward the middle of the next lower step, releasing your hold (with this action, potential energy is converted to kinetic energy). The Slinkys race downward all by themselves.
4. After the race, ask why the smaller Slinky won. (As the Slinky moves down the steps, energy is transferred along its length in a longitudinal or compressional wave which resembles a sound wave that travels through a substance by transferring a pulse of energy to the next molecule. How quickly the wave moves through the Slinky depends on the tension and mass of the coil. The smaller the mass, the tighter the tension; the tighter the tension, the faster the wave speed. So, the wave moves faster through the smaller Slinky.)

Activity No. 1 provided by the engineers of ConocoPhillips.



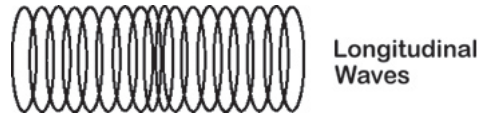
Activity #2: Slinky Waves

A Slinky can easily demonstrate the two basic types of waves, longitudinal and transverse, as well as several others. A longitudinal wave vibrates parallel to (in the same direction of) wave travel (sound waves are a good example). A transverse wave vibrates perpendicular (at right angles) to the wave travel (water waves are a good example).

To demonstrate the types of waves:

Have two students each take one end of a Slinky and stretch it out along the floor (the waves will be more apparent this way).

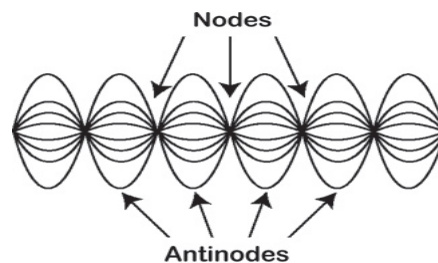
Longitudinal Waves. Have one student grasp and draw toward himself or herself several coils of a stretched metal Slinky and then release the coils. The other student must hold his or her end of the Slinky still. A longitudinal wave pulse will be generated and travel down the length of the Slinky.



Transverse Waves. Have one student move his or her end of a plastic or metal Slinky back and forth (left and right, like a snake crawling), perpendicular to its stretched length. The other student must hold his or her end of the Slinky still. A series of transverse waves will be generated.



Standing Waves. When a series of wave pulses are sent through a medium and then reflected back upon themselves, standing waves can be generated, as demonstrated in the space shuttle footage in the video, Slinky Scientific Shindig. These distinctive waveforms have places where the medium does not vibrate at all, called nodes, and other places where the medium vibrates the most, called antinodes. When the students are demonstrating transverse waves, standing waves with varying numbers of nodes and antinodes can be generated by having the student moving the Slinky vary the rate at which he or she continually moves it back and forth.



Compressions and Rarefactions. Longitudinal waves can be composed of compressions, where the parts of the medium (coils of the Slinky) are closer together than normal, or rarefactions, where the parts of the medium are farther apart than normal. In the above demonstration, the students created compressional longitudinal waves. A rarefactional longitudinal wave can be produced by stretching a segment of the Slinky and then releasing it.

The stretched area (rarefaction) will then travel along the length of the Slinky.

Activity No. 2 and graphics provided by Granger Meador, physics teacher, Bartlesville (Oklahoma) High School.

Activity #3: Slinky and Centrifugal Force

Slinkys also can demonstrate centrifugal force. Here's how. Hold a Slinky by several coils at one end; then circle it around your head (like swinging a lariat), gradually increasing the speed. The position of the Slinky shows the resultant force formed by two simultaneous forces. The downward and vertical force is the force of gravity. The outward and horizontal force is the centrifugal force. (Another example of centrifugal force is clothes spinning in a washing machine.)

Activity No. 3 adapted from "Slinky History." Messiah. Online. America Online. 12 May 1997.

Slinky® Science Teaching Guide

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Engineers

From the time prehistoric cavemen invented the wheel to the days American Indians first used a travois to haul their possessions and scientists created the spaceship, engineers have played a major role in our destiny. In ancient times, engineers built roads and structures by trial and error, learning from their own mistakes. Today, college training prepares an engineer to work in a certain branch or field of engineering.

What Do Engineers Do?

Engineers apply the theories and principles of science and mathematics to the economical solution of practical technical problems. Often their work is the link between a scientific discovery and its application. In addition to design and development, many engineers work in testing, production or maintenance. They supervise production in factories, determine the causes of breakdowns, and test manufactured products to maintain quality. They also estimate the time and cost to complete projects. Some work in management or sales where an engineering background enables them to discuss technical aspects of a product and assist in planning its installation or use.

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Types of Engineers

Engineers can be classified into 11 types, according to the kind of work they do—construction, consulting, design, development, teaching, planning (also called applications engineers), production, research, sales, service, and test engineers.

They work in laboratories, industrial plants, or construction sites where they inspect, supervise or solve on-site problems; others work in an office most of the time, and a few travel extensively to plants or construction sites. Engineers in branches such as civil engineering may work outdoors part of the time.

Engineers in each branch have knowledge and training that can be applied to many fields, and because there are numerous separate problems to solve in a large engineering project, engineers in one field often work closely with specialists in scientific, other engineering, and business occupations.

Most specialized engineering we know today developed during the last 200 years. Before then, engineering dealt mostly with the construction of roads, bridges, canals, or military structures and devices. As mankind gained more knowledge of science and technology, engineers began to specialize in certain kinds of work.

Specialized engineering fields are numerous and include aerospace • agricultural • architectural • automotive • biomedical • ceramic • chemical • civil • computer science • electrical • engineering physics • environmental health and sanitary • geological • marine • mechanical • metallurgical and materials • mining • nuclear • ocean • petroleum • systems • textile • and transportation.

Education and Jobs

Beginning engineering jobs usually require a bachelor’s degree in engineering from an accredited program, but in engineering specialties in high demand, physical science or mathematics degree-holders may qualify for some jobs.

Engineering bachelor’s degree programs typically are designed to last four years, but many students find that it takes between four and five years to complete their studies.

Most engineering degrees are granted in branches such as chemical, mechanical, civil or electrical engineering. In addition to the standard degrees, many colleges offer degrees in engineering technology. These programs prepare students for practical design and production work rather than for jobs that require more theoretical, scientific and mathematical knowledge.

Graduate training is essential for engineering faculty positions but is not required for the majority of entry-level engi-

neering jobs. Many engineers obtain a master's degree to learn new technology, to broaden their education, and to enhance promotion opportunities.

Training

Beginning engineering graduates usually do routine work under the supervision of experienced engineers and, in larger companies, may also receive formal classroom or seminar-type training. As they gain knowledge and experience, they are assigned more difficult tasks with greater independence to develop designs, solve problems, and make decisions.

Necessary Traits

- Engineers should be able to work as part of a team and should have creativity, an analytical mind, and a capacity for detail.
- Engineers should be able to express themselves well, both orally and in writing.
- The ability to work with mathematics is probably the most important qualification for an engineer.

Many personal traits also qualify a person for an engineering career. A person who enters engineering should be:

- curious, searching for the "how" and "why" of natural and mechanical things;
- intelligent, thinking clearly and using sound judgment;
- imaginative, picturing difficult situations and suggesting new ideas or new ways of doing things;
- creative, bringing new facts and methods together to solve new problems;
- industrious, working hard to complete exacting tasks as quickly as possible;
- studious, reading widely and extensively to increase knowledge;
- responsible, completing assignments in a dependable way with a minimum of supervision;
- communicative, sharing ideas with others and getting along with people.

Employment and Outlook

Job opportunities for engineers are expected to remain good, and employment is expected to increase about as fast as the average for all occupations through the year 2005, while the number of engineering degrees is expected to remain near present levels.

Employers will need more engineers as investment in plants and equipment is increased to further increase productivity and expand output of goods and services. More engineers also will be needed to improve deteriorating roads, bridges, water and pollution control systems and other public facilities.

Earnings

Starting salaries for engineers with the bachelor's degree are significantly higher than starting salaries of bachelor's degree graduates in other fields.

According to the National Society of Professional Engineers, the 1996-97 recommended entry-level salary average for engineering graduates with a bachelor's degree was \$37,355. For experienced mid-level engineers, the recommended salary range was \$56,032 to \$95,255. Recommended annual earnings for engineers at senior managerial levels ranged from \$112,065 to \$168,098 and well above.

Slinky® Science Classroom Activities

Manufacture a CD Crate

Throughout history, people have attempted to fulfill their basic needs. When the pioneers needed household items, they simply built their furniture or made their clothes. In contrast, Henry Ford organized a huge factory to build his Model T-cars, including an assembly line with hundreds of workers and materials from across North America.

Modern manufacturing occurs in a variety of areas, not just the factory. Look around for simplified examples of manufacturing. For example, copied papers that are assembled into a booklet; sewing a dress; and assembling and painting a toy model car. These are simplified production lines, used by individuals to build dozens of simple products.

Activity

Building a CD crate will show you the difference between a custom-built product and a mass-produced product. To manufacture a product, companies first identify a need. In this case, the need is something in which to store compact disks. Engineers then identify ways in which CDs can be stored. A design is developed and tested. Once the design is accepted, the product must be manufactured. But how?

The product can be custom or mass produced. In this activity, you will custom produce a crate, while comparing it to ways in which the product could be mass produced.

Materials

- Styrofoam blocks or pine wood
- 2 ends— $3/4$ " x $5-5/8$ " x $5-5/8$ "
- 6 slats— $1/4$ " x $3/4$ " x 12"
- Hot glue gun or small nails or staples

Tools

- Hammer or staple gun
- Saw
- Tape measure

Design for End of CD Crate

- Labels or stickers

1. In a custom setting, all pieces are made one at a time, by hand. Cut wood or Styrofoam pieces to required dimensions.
2. Once cut, check pieces for quality—no cracks, splits, etc.
3. Assemble all pieces and attach with nails, staples, or glue.
4. Crate is finished. Again check for quality.
5. Put decoration on both ends of crate.

In a custom-built setting, a second crate is not started until after the first crate is finished.

In a mass production setting, wood or Styrofoam could arrive precut or be cut on-site. For this example, the pieces are

cut on-site. The tools needed for production are the same as above.

In manufacturing, each individual on the production line has a specific responsibility.

Person 1 - cuts the slats

Person 2 - cuts the ends

Person 3 - attaches the side slats to the ends, forming the start of a crate

Person 4 - attaches the bottom slats to the started crate, finishing the crate

Person 5 - attaches the decoration and checks for the quality of the product.

Because each person is doing only one part of the job, the assembly of the product goes much faster. They can concentrate on getting only one job done, instead of moving from one step to the next.

If 1,000 CD crates were being produced, who do you think would get the job done faster? Individuals or the production line?

(Activity provided by the Society of Manufacturing Engineers.)

Slinky® Science Classroom Activities

Decision Package

The problem: Create a package that will prevent an egg from breaking when it is tossed into a large box.

First, divide students into teams; then provide each team with the following:

- an egg
- an envelope containing:
 - 1 mailing label or computer label
 - 1 piece of 8 1/2" x 11" paper
 - 1 rubber band
 - a 12" piece of string
 - 1 paper clip
 - a 1" piece of tape to keep the envelope closed
- 1 box, approximately 18" square.

Students can complete their packaging design in about 10 minutes, using good teamwork. Testing and discussion will fill the rest of the period.

After the students complete their packaging, have each team toss their "package" into the box. The box should be on the floor about 8 feet from the tossing line. If the package misses the box, it must be tossed again. Once the package is in the box and there is no evidence the egg broke, put it back into the box and have the students drop the box, with the package in it, onto the floor from a height of 5 feet.

Many adaptations of this problem can be used and scoring systems can be devised for each. For example, students may wish to use some of the "packaging materials" on the egg and some on the box; the "dropping height" can be changed, etc. Each change allows for new discussion of why the eggs did or didn't break.

(Variation of activity by Odyssey of the Mind. Glassboro, New Jersey. 1988.)

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Great Engineering Feats

Most people have heard of the Seven Wonders of the World, but what many don't know is that we have engineers to thank for creating such remarkable objects.

The practice of listing the Seven Wonders began in ancient times, when Greeks and Romans compiled lists of memorable things that travelers should see. Numerous lists were made that included many different wonders, but all the lists of ancient wonders included only objects created by human beings (ancient engineers) and considered notable because of their size or other unusual quality.

Students might find it fun and interesting to do a little research about the ancient wonders. For example, with no machinery or iron tools, how did ancient man build such marvels? Why did all but one disappear?

Ancient Wonders

- **Pyramids of Egypt**, oldest of all the ancient wonders and the only one still standing. The largest, the Great Pyramid, is a marvel of building skill, containing more than 2 million stone blocks that average 5,000 pounds each.
- **Hanging Gardens of Babylon** near modern Baghdad, Iraq. No positive trace of the gardens remains, but scholars know about them from an account by a Babylonian priest of the 200s B.C.



- **Temple of Artemis at Ephesus**, one of the largest and most complicated temples built in ancient times.
- **Statue of Zeus at Olympia, Greece**; perhaps the most famous statue in the ancient world.
- **Mausoleum of Halicarnassus**, in what is now southwestern Turkey, was a huge marble building built as a tomb for Mausolus, an official of the Persian empire. Its size and decorations made it so famous that all large tombs are now called mausoleums.
- **Colossus of Rhodes**, a huge bronze statue that stood near the harbor of Rhodes on the Aegean Sea. In 224 B.C., the statue was destroyed by an earthquake.
- **Lighthouse of Alexandria** stood on the island of Pharos in the harbor of Alexandria, Egypt. It became so famous that the word "pharos" came to mean lighthouse.

Channel Tunnel

The astounding feats of engineers are what first draw many to the profession. Whether it is forging the Suez Canal or building a motor the size of a flea, engineers dream of conquering the great "impossibilities." That dream became a reality for mechanical engineer John Neerhout who in 1990 seized his opportunity to achieve the impossible. He was asked to take over as project chief executive for construction of a double railway tunnel scheme for a Channel Tunnel (Chunnel), a fixed link joining France and England across the English Channel.

Owned by Eurotunnel, the visionary project had been plagued by severe cost, schedule and safety problems. The operation was incredibly complex. Linking two countries, the project required working in two languages with two gov-

ernments; two sets of national construction, safety and legal codes; 10 contractors; and 220 syndicate banks. By all accounts, Neerhout's leadership, technical know-how and management turned the project around. Today the 32-mile "Chunnel" is an engineering wonder. Completed at a cost of \$12 billion, it is the world's largest privately financed engineering endeavor.

Golden Gate Bridge

This famous bridge isn't named for its color, but for the entrance to San Francisco Bay, which was dubbed the "Golden Gate" some 150 years ago by prospectors who passed through it on their way to California's gold fields.

The color, called international orange, was chosen by consulting architect Irving Morrow, who rejected the traditional gray or black in favor of the color he thought best complemented the bridge's natural setting. The 1965 project to replace all the original lead-based paint (with a non-toxic zinc silicate primer and acrylic emulsion) took 30 years to finish, and touch-up work continues.

When completed in 1937, the Golden Gate was the world's longest suspension bridge (1.7 miles) and the highest structure west of New York (745 feet). Today people can walk across the east side of the bridge or cycle across the west side during daylight hours.

To learn more about the Golden Gate, go to www.goldengatebridge.org.

Panama Canal

Truly one of the great engineering feats of all time, the Panama Canal was designed at the turn of the 20th century and has been operating since 1914. It is 50.72 miles long, some of it hewn from solid rock, and gives passage to all types of vessels, from huge tankers to the Queen Elizabeth II.

A canal across Central America fulfilled dreams of a short route from Atlantic to Pacific ports by allowing ships to enter the Pacific Ocean without traveling entirely around South America.

The United States built the canal at a cost of about \$380 million. Thousands of laborers worked on it for about 10 years, using steam shovels and dredges to cut through jungles, hills and swamps. They removed 211 million cubic yards of earth and rock and had to conquer malaria and yellow fever.

The canal has three sets of water-filled chambers (locks), which raise and lower ships from one level to another. The locks were built in pairs to allow ships to pass through in both directions at the same time. The United States has controlled the Panama Canal Zone and the canal since 1903. However, a treaty approved by Panama's voters in 1977 and by the U.S. Senate in 1978 will give Panama control of the canal on Dec. 31, 1999.

Eiffel Tower

Another undisputed great engineering feat is the Eiffel Tower, a huge wrought-iron skeleton in Paris. Alexandre Gustave Eiffel designed the 984-foot tower for the exposition of 1889.

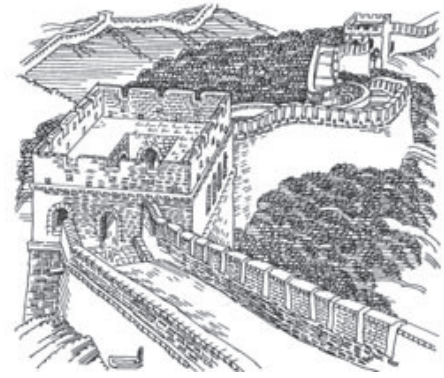
The Eiffel Tower contains about 7,000 short tons of iron and steel and cost more than \$1 million. For many years, it was the highest structure in the world and served as an important military observation station during World War I. Since 1953 it has been used to transmit television programs.



Great Wall of China

One of the most famous structures in the world can be found to the northwest and north of Beijing, China. Said to be visible from the moon, the Great Wall is the longest fortified line ever built. It zigzags to the east and west along the mountains, stretching more than 1,500 miles.

Construction of the Great Wall began in the 7th century B.C. It stands about 25 feet high and has 40-foot towers built into it every 200 to 300 yards. The wall tapers from a 25-foot base to about 15 feet at the top. Its sides are made of earth, brick and stone, while the top is paved with bricks set in lime, forming a roadway for horsemen. The Great Wall was built entirely by hand and took hundreds of years to complete.



Roman Aqueducts

Good architects and engineers combine the needs of human beings with qualities of intellect and imagination, as well as technical expertise to create functional structures that also are works of art. For example, ancient Roman aqueducts provided the function of transporting water in the form of simple, yet elegant, layered arches.

An aqueduct is an artificial channel through which water is conducted to the place where it is used. Most aqueducts of ancient times were built of stone, brick or pozzolana, a mixture of limestone and volcanic dust. Rome had many aqueducts and was the only ancient city reasonably supplied with water. By A.D. 97, nine aqueducts brought about 85 million gallons of water a day from mountain springs. Later, five others were built. About 200 cities in the Roman colonies had aqueducts.

Roman Colosseum

The Colosseum, which stands near the center of present-day Rome, is perhaps the finest surviving example of ancient Roman architectural engineering. One of the most famous ruins in the world, thousands of tourists visit it every year.

The Colosseum is shaped like a modern football stadium and could seat 45,000 spectators. The four-story facility is 161 feet high, about 600 feet long and 500 feet wide. Events such as fights between gladiators and between men and wild animals were held there. Awnings could be hung from the walls to protect spectators from the sun.

The oval-shaped, sand-covered floor of the arena originally could be flooded for water spectacles. Later, however, cages for people and animals were installed beneath the arena. A wall separated the arena from spectators whose seats rested on sloping concrete supports as in many stadiums today.

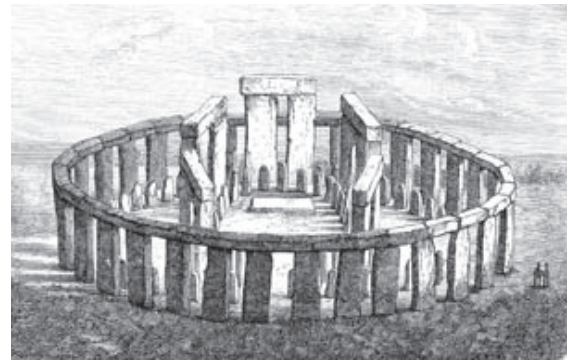
Construction of the Colosseum started during the reign of Emperor Vespasian, who ruled from A.D. 69 to 79. Construction was completed in A.D. 80.

Stonehenge

This ancient monument of huge, rough-cut stones standing alone on the Salisbury Plain in Wiltshire, England, has captured imaginations for centuries. No one knows exactly who placed them there or why. Speculation ranges from human sacrifice to astronomy. It seems to have been designed to allow observation of astronomical phenomena--summer and winter solstices, eclipses and more.

Stonehenge was built in three stages from about 3000 to 1800 B.C. The first stage was a circular earth formation; the second consisted of timber being added to the circle; and the third stage was constructed of bluestones. Two hundred to 300 years later, the sarsen stones were added. These are taller than the bluestones and form the upside-down "u" now seen.

Perhaps the most impressive part of Stonehenge is how it was built. The first phase, the ditch around Stonehenge, was dug using antlers, bones and even bare hands. The bluestones, which weighed four tons each, came from over 240 miles away. They had to be floated by boat then carried across land. The heaviest sarsen stone weighed 50 tons and would have had to be dragged along by 500 people. Even if 600 people had been working continuously, it would have taken more than a year to complete. For hundreds of years, the great stones of Stonehenge gradually fell, or people carried them away to make bridges and mill dams.



Washington Monument

This great obelisk was built in honor of George Washington and stands in Washington, D.C., near the Potomac River about halfway between the Capitol and the Lincoln Memorial. The monument is over 555 feet high and measures over 55 feet along each of its four sides at the bottom.

The walls are 15 feet thick at the bottom and 18 inches thick at the top. They are covered with white marble from Maryland, and the stones covering the pyramid are seven inches thick.

Inside, the monument is hollow. The inner walls are set with 189 carved memorial stones which were presented by individuals, societies, cities, states and other countries.

The cornerstone was laid on July 4, 1848, with the same trowel that Washington had used to lay the cornerstone of the Capitol in 1793. But engineers found the ground too soft to support the monument, so they moved the site to the north. Work began Aug. 17, 1880, and was completed Dec. 6, 1884, at a total cost of \$1.2 million. The monument was dedicated in 1885 and opened to the public in 1888. Today it is maintained as a national memorial by the National Park Service.

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Slinky® Science Classroom Activities

Structures (Civil Engineering)

The following comes from Structures, a 1986 exhibit at the Franklin Institute Science Museum.

Buckling

Push on the ends of a piece of uncooked spaghetti. The sideways bending is called buckling. The compression force that you apply causes complex internal forces that bend the spaghetti sideways. If you push hard enough, it will snap. The snapping starts on the edge where the tension force within the spaghetti is great enough to pull it apart.

Brittle materials like spaghetti, stone or glass break rather easily this way. Stone columns must be made so they won't buckle—because once they start to buckle, they will collapse.

Suspension Bridge

Tie a string between two books. Push down on the string. The “cable” pulls down and inward, toppling the books.

Now set up the books on a board. Pass the string over the books to thumbtack-anchors on the ends of the board. Push down slowly, harder and harder. You'll be able to put a lot of load on the string-cable; you may even be able to push hard enough to lift the thumbtacks out of the board.

(Activity provided by Construction Specifications Institute.)

It's A Wonder!

After a classroom discussion of the Seven Wonders of the World, arrange the students in small groups and have them pretend they are a team of engineers commissioned to create a modern-day wonder for which cost is no object. Let their imaginations run wild; then have them make a presentation to the rest of the class, using mock-ups or drawings and a very brief written description of their project (tell them an outline will suffice). The next day, post all of the presentation sheets so that every “wonder” idea can be shared with all of your classes.

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After a classroom discussion of the Seven Wonders of the World, arrange the students in small groups and have them pretend they are a team of engineers commissioned to create a modern-day wonder for which cost is no object. Let their imaginations run wild; then have them make a presentation to the rest of the class, using mock-ups or drawings and a very brief written description of their project (tell them an outline will suffice). The next day, post all of the presentation sheets so that every “wonder” idea can be shared with all of your classes.

Slinky® Science Teaching Guide

This teaching guide is designed to complement the 20-minute video, Slinky® Science.

Serendipity: Science and Discoveries

What do the discovery of America, the invention of the telephone and the creation of vulcanized rubber have in common? All came about as the result of serendipity—the ability of making fortunate discoveries by accident.

Throughout the centuries, written records have told of “miracles” that led to some of the world’s greatest medical breakthroughs, machinery, and scientific victories. That’s just as true for the 20th century as it was in the 1400s.

Polypropylene

Phillips Petroleum Company, now ConocoPhillips, got into the plastics business quite by accident.

It began on June 5, 1951, when two young Phillips research chemists, J. Paul Hogan and Robert L. Banks, were experimenting with catalysts to make higher-octane gasoline from propylene and ethylene.



To their surprise, the lab equipment became clogged with a whitish, tacky-looking substance. They knew they had made something unique and carefully recorded the procedure they had used and all details about the substance. Hogan and Banks had discovered a new plastic—crystalline polypropylene. Shortly thereafter, they made a similar plastic, crystalline polyethylene. On Jan. 27, 1953, a patent was filed. Phillips committed the then enormous sum of \$50 million to build a large-scale polyethylene plant near Houston.

As for polypropylene and polyethylene—they are used to produce the vast majority of the thousands of plastics products throughout the world today. ConocoPhillips’ plastics are now produced through the Chevron Phillips Chemical Co. joint venture.

The Americas

Christopher Columbus was looking for a new trade route to the Orient in 1492 when he unexpectedly came upon the Americas. Underestimating the world’s size, he thought he had somehow missed Japan after having sailed 3,000 miles, and that the islands he found belonged to the East Indies south of Japan.

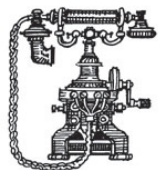
Columbus died believing he had found new areas of the Orient rather than a new continent, and he never profited from his discoveries in the way he had hoped.



What makes his find “serendipitous” is the development of civilization in the New World, which came long after the explorer’s historic discovery.

The Telephone

The first telephone came about in 1875, also as a result of an accident. Alexander Graham Bell, with help from his



assistant Watson, built a kind of electromechanical ear in the quest to create a “speaking telegraph.”

Watson had been trying to transmit telegraph signals, and when one of the metal reeds got stuck, he plucked it in an effort to break it free. Bell came rushing into the room to find out what Watson was doing, because he had heard a strong signal from the receiving reed in the other room, strong enough that he knew he could use this simple device to transmit speech. Like many other inventors, Bell took advantage of accidents and mistakes that would have been ignored by someone else.

Rubber

American inventor Charles Goodyear tried for five years to find a way to make rubber a useful product. He wanted rubber that would not melt in the heat or become brittle and stiff in the cold. He applied various treatments to the substance, but none worked. One winter night in 1839, Goodyear accidentally dropped a piece of rubber sprinkled with sulfur onto a red-hot stove. To his astonishment, instead of melting, the rubber flattened out into a small disk. Lifting it from the stove, he found it was still flexible and strong. He then hung the disk on his doorpost overnight in the winter cold. The next morning, the disk still had its rubber-like qualities. Goodyear had accidentally invented vulcanization—the process of heating rubber treated with sulfur to give the rubber elasticity, hardness and strength.



Many more products that we take for granted owe their discovery to serendipity, which also can be defined as chance observation falling on a receptive eye. Examples of such discoveries follow.

Vaccination

Edward Jenner, an English physician, accidentally discovered the vaccine that saved many millions of people from death from smallpox. It happened one day when he recalled a milkmaid telling him that she could never have smallpox because she had had cowpox. The idea struck him that he could inoculate patients with cowpox to keep them from having the more deadly smallpox. This was true serendipity. The fact that cowpox gave immunity to smallpox came to him without effort on his part. He had the good judgment to recognize its value and make use of it.

Penicillin

Perhaps the best-known important accidental discovery occurred in 1922 when Sir Alexander Fleming discovered an antibiotic that killed bacteria but not white blood cells as did carbolic acid, the most common antiseptic at that time. While suffering from a cold, Fleming made a culture from some of his own nasal secretions. As he examined the culture dish filled with yellow bacteria, a tear fell from his eye into the dish. The next day, he found a clear space in the culture where the tear had fallen. His keen observation and inquisitiveness led him to the correct conclusion: the tear contained a substance that caused rapid destruction of the bacteria, but was harmless to human tissue.

That discovery was vitally important when in 1928 Fleming was conducting research on influenza and noticed that one dish had an unusual clear area where a bit of mold had fallen into it. Remembering the “tear” experience, he concluded that the mold was producing something that was deadly to the staphylococcus bacteria in the dish. He isolated the mold, which resulted in penicillin.



Velcro

Perhaps the world’s most ingenious and versatile fastening method is the hook and loop fastener known by the trade name Velcro®. The idea for the unique fastener came from an accidental observation. In the early 1950s George deMestral went for a walk in the countryside of Switzerland. Returning home, he noticed that his jacket was covered with cockleburs. As he began picking them off, he wondered what made them stick so tenaciously.

Curiosity led him to use a microscope to investigate more carefully. He discovered that cockleburs are covered with hooks, and the hooks had become embedded in the loops of the fabric of his cloth jacket. DeMestral wondered whether a system patterned after the cocklebur could be designed that would be useful rather than a nuisance...and the rest is fastener history. Today cocklebur-type hooks and woven loops secure everything from children’s shoes to microphones in space shuttles. The name “Velcro” is derived appropriately from velvet and crochet.

Slinky® Science Fun and Games

While the list of accidental scientific discoveries appears to be endless, many games and toys also are the result of serendipity. Here are a few of them.



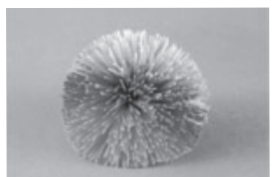
Frisbee. This popular flying disc actually came about after students at Yale University finished eating pies from a local bakery called Frisbie's and began tossing around the empty, saucer-shaped pie tins. A California carpenter invented a plastic variation and called it the Pluto Platter. Wham-O, a company then known for the Hula Hoop, bought the rights and renamed it.



Play-Doh first originated as a wallpaper cleaning compound at a Cincinnati-based company making soap and cleaning solutions. Instead of manufacturing it as a cleaning product, the company realized its toy potential, and Play-Doh, the original, reusable modeling compound, was born. More than 2 billion cans of Play-Doh have been sold since 1956.



Lego. The Lego Brick was created in 1932 by a poor Danish carpenter who, after struggling to earn a living in his construction and furniture-making business, turned to making wooden toys. He sold many wooden toys of all kinds and, in 1934, he named his toy company Lego, based on a contraction of two Danish words leg godt, meaning "play well." The company began making plastic building blocks in the late 1940s, and the Lego System of Play was developed. The Lego Toy Company is still family-run and children spend over 5 billion hours each year playing with Lego toys.



Koosh Ball. This popular ball was actually invented in 1987 to teach young children how to catch. Engineer Scott Stillinger found that his children's small hands couldn't easily grasp balls during a game of "catch," so he tied rubber bands together to make a small, catchable ball that was easy for small fingers to hold onto. Listening to the "koosh" sound the ball made as it landed in his hand, the inventor realized that was the perfect name and the Koosh Ball was born. How many rubbery strands does it take to create the energy-absorbent, porcupine-look of a Koosh Ball? Approximately 5,000 fibers go into each ball.

Classroom Discussion

1. Ask students to list unusual uses they have found for everyday items (i.e., a metal clothes hanger as a radio antenna or to gain access to a locked car with the keys inside). Also ask how they came up with the idea (was it spontaneous or had they seen someone else doing the item in a similar manner?). Appoint a class recorder to list the unusual applications on paper as you list them on the chalkboard or overhead projector. Keep the list made by the "secretary" for comparison with unusual applications in other classes. The next class day, share all of the unusual applications with each class and discuss which is the most serendipitous.

2. Ask the class to suggest items they'd like to see improved--perhaps the classroom chair, the bathtub, bicycle, or automobile. Then ask them to describe improvements. Require that they be specific. For example, instead of just saying they'd make the bathtub interior soft, insist that they explain what material could be used and why. Foam rubber might be comfortable, but is it sanitary? Does it mildew, tear, or slip easily? How would they test their ideas? Why are research and testing important?

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Slinky® Science Teaching Guide

This teaching guide is designed to complement the 20-minute video, Slinky® Science.

How are Plastics Made?

Forty years ago, anything made of plastic was considered “cheap.” That’s certainly not true today when plastics are used in thousands of products ranging from computers, automobile parts and important medical equipment to toys, cookware, sports equipment, and even clothes. And the plastics industry continues to grow rapidly. Just where do plastics come from?

What are plastics?

It may surprise students to learn that gutta-percha, shellac, and the horns of animals—all naturally occurring substances—were used as plastic material before the first synthetic plastics were produced. Gutta-percha is derived from the sap of certain trees, and shellac is made from the secretions of a tiny scale insect. Before horn can be used, however, it must be “plasticized,” or softened, by being boiled in water or soaked in an alkaline solution.

The first synthetic plastic was made from the plant material cellulose. In 1869, John Wesley Hyatt, an American printer and inventor, found that cellulose nitrate could be used as an inexpensive substitute for ivory. The mixture could be plasticized with the addition of camphor. Celluloid, as this new material was called, became the only plastic of commercial importance for 30 years. It was used for eyeglass frames, combs, billiard balls, shirt collars, buttons, dentures, and photographic film.

In 1951, two young research chemists for Phillips Petroleum Company (now ConocoPhillips) in Bartlesville, Okla., made discoveries that revolutionized the plastics world. Today, the plastics they discovered—polypropylene and polyethylene—are used to produce the vast majority of the thousands of plastics products all over the world. (Read more about their discoveries in “Serendipity, Science & Discoveries” in this publication.)

The source for today’s wide variety of plastics? Petroleum.

Petroleum to Plastics

The technological road from oil field to finished plastic product has numerous fascinating side trips. Here’s the route taken in the petroleum-to-plastics process:

1. Petroleum is drilled and transported to a refinery.
2. Crude oil and natural gas are refined into ethane, propane, hundreds of other petrochemical products and, of course, fuel for your car.
3. Ethane and propane are “cracked” into ethylene and propylene, using high-temperature furnaces.
4. Catalyst is combined with ethylene or propylene in a reactor, resulting in “fluff,” a powdered material (polymer) resembling laundry detergent.
5. Fluff is combined with additives in a continuous blender.
6. Polymer is fed to an extruder where it is melted.
7. Melted plastic is cooled then fed to a pelletizer that cuts the product into small pellets.
8. Pellets are shipped to customers.
9. Customers manufacture plastic products by using processes such as extrusion, injection molding, blow molding, etc.

Plastics Processing Methods

Extrusion Molding -- the main process used to form plastics. A heated plastic compound is forced continuously through a forming die made in the desired shape (like squeezing toothpaste from a tube, it produces a long, usually narrow, continuous product). The formed plastic cools under blown air or in a water bath and hardens on a moving belt.

Rods, tubes, pipes, Slinkys®, and sheet and thin film (such as food wraps) are extruded then coiled or cut to desired lengths.

Plastic fibers also are made by an extrusion process. Liquid resin is squeezed through thousands of tiny holes called spinnerets to produce the fine threads from which plastic fabrics are woven.

Injection Molding -- is the second most widely used process to form plastics. The plastic compound, heated to a semi-fluid state, is squirted into a mold under great pressure and hardens quickly. The mold then opens and the part is released. This process can be repeated as many times as necessary and is particularly suited to mass production methods. Injection molding is used for a wide variety of plastic products, from small cups and toys to large objects weighing 30 pounds or more.

Blow Molding -- pressure is used to form hollow objects, such as the soda pop bottle or two-gallon milk bottle, in a direct or indirect method. In the direct blow-molding method, a partially shaped, heated plastic form is inserted into a mold. Air is blown into the form, forcing it to expand to the shape of the mold. In the indirect method, a plastic sheet or special shape is heated then clamped between a die and a cover. Air is forced between the plastic and the cover and presses the material into the shape of the die.

Slinky® Science Classroom Activities

Plastics: Imagine Life Without Them

Suppose you could step inside a time machine and go back 60 or 100 years. You may easily convince yourself a day without cars, telephones, and television—maybe even computers—might be kind of fun. Have you thought about the little things, though? Little things are often what are missed the most.

Imagine a day without touching something made of plastic!

People were cleaning their teeth before there was a choice of red, blue or purple plastic toothbrushes, but would you really want one made from metal or wood? Milk and shampoo used to be sold in glass bottles, and that wasn't a problem unless you dropped one and it broke. What a mess!

The word plastic comes from the Greek word *plastikos*, meaning "able to be molded." That characteristic, or what scientists call "property," makes plastic perfect for things like action figures and dolls. What other properties does plastic have that make it a good choice for particular products? Try these experiments, then use what you learn to list 10 or even 20 good candidates for plastic.

Materials

- pieces of aluminum, plastic, and wood about the same size (approximately 2' long, 1" wide, and 1/8" thick (rulers or yardsticks might work)
- two 6" stacks of books
- a 2-pound canned good item
- a 4-foot length of string
- a tennis ball
- a plastic and a paper grocery sack.

Place the two stacks of books about 9" apart. Lay the aluminum strip across the books, making a level bridge. Lay the string parallel to the strip. Next place the canned good in the middle of the strip. Use the string to measure the deflection (bend) in the strip and write down your observation.

Repeat the process with the wood and plastic, then discuss what you have observed about the strength and stiffness of each material. (Which material would you choose for a toothbrush handle? How about the toothbrush bristles?)

Next, soak the tennis ball in water until it is thoroughly wet. Place it first in the plastic sack and then the paper one, letting it sit in each for 5 minutes before shaking each bag vigorously. Which bag stays dry? Does the water cause the paper bag to sag and even break? What can you conclude about how each material repels or absorbs water? Which bag would you choose to carry your carton of ice cream?

The information, or data, you've gathered from your experiments is just what a scientist uses to decide what material to use in an engineering design!

(Activity provided by the engineers of ConocoPhillips)

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