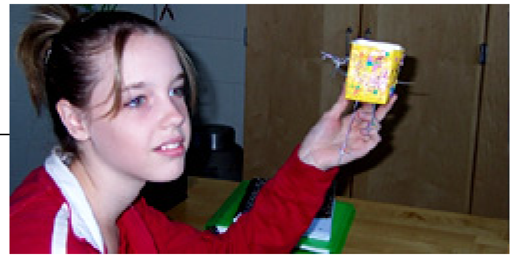
Session 5

Making Machines

Engineering Fundamentals



In This Session:

A) Design, Build, Make It Go (40 minutes)
- Student Handout
- Student Reading

B) Not-So-Simple Machines (40 Minutes)
- Student Handout
- Student Reading

C) Gears, Cranks, Crankshafts, and Belts (70 Minutes)
- Student Handout

Home Improvement
- Student Handout

This session really puts things in motion. In *5A: Design, Build, Make It Go*, students make rolling toys from a set of everyday materials in a mini-design challenge, and then recall prior experiences with simple machines. To understand that most machines are made of many smaller machines, students study the component machines in a lawnmower through a Web-based tutorial, in *5B: Not-So-Simple Machines*. Students also participate in a mini design challenge to create a simple machine. The activity *5C: Gears, Cranks, Crankshafts, and Belts* is an exploration of gears, cranks, crankshafts, and belts, and culminates in the design, conceptual drawing, and initial construction of a mechanical toy. As a Home Improvement activity, *Build a Mechanical Toy*, students take their plans and materials home and finish their toy.

Supplies

Examples of Stored Energy Toys

- Rubber band airplane, windup toys, paddleball, yo-yo, Slinky*, etc.

One "Rolling Kit" Per Student

- 1 film canister with lid, with holes drilled in both ends
- 2 size #30 or #31 rubber bands (dimensions 2.5" x 1/8" x 1/36" [6.5 cm x 3 mm x 0.7 mm], #31 is slightly heavier)
- 2 washers (either ½" or ¾" [1.25 cm or 2 cm] outside diameter)
- 1 piece of thick drinking straw the length of the canister

Simple Machine Examples

- Wedge: chisel, saw, screwdriver, scissors, door wedge, thumbtack, pins
- Wheel and axle: doorknob, roller skates, eggbeaters, pencil sharpener, skateboard
- Screw: nuts and bolts, jar lid, lightbulb, key rings, corkscrew
- Pulley: flagpoles, clotheslines, blinds, crane, fan belt
- Lever: see saw, wheelbarrow, hammer, crowbar, bottle opener, oar, fork, baseball bat
- Inclined plane: wheelchair ramp, slide, hill, roller coaster, escalator

Session 5, Making Machines (continued)

Simple Machine Challenge

- 1 washer (either ½" or ¾" [1.25 cm or 2 cm] outside diameter) per group
- 1 plastic or paper cup per group
- Meter sticks
- Brads, clay or play-dough, clothespins, craft glue, craft sticks, dowels, drinking straws, foam pieces, gears, hot glue, magnets, paper clips, pipe cleaners, plastic bags, plastic spoons, plastic/paper cups, pulleys, rope, rubber bands, scissors, spools, springs, string, tape, wire

Optional Mechanical Parts

- Gears set
- Wheels set
- 1/4"-wide rubber band "belts" (size #64)
- Small wooden dowels (Bamboo skewers will work.)

One Crankshaft Kit Per Student

- Small box (8 oz. milk carton will do)
- 3 pieces 16-gauge steel wire: one 8" (20 cm) length, two 3" (7.5 cm) lengths
- 1 straw
- Electrical tape or long bead (for crank handle
- Several pairs of needle-nose pliers

Other

- Tools that use moving parts: eggbeaters, hand drills, winged corkscrews, flour sifters, ice cream scoopers, nut grinders, and manual can openers
- Miscellaneous gears, belts and wheels, wire, art supplies, and other materials of choice

Making Machines

Key Concepts: Session 5

Session 5 explores fundamental physical science concepts of **mechanical engineering**. A rolling-toy design challenge begins students thinking about machines. Students go on to explore the mechanics of simple machines and learn that most mechanical devices are really a set of simple machines working together. They learn how machine action can be transferred or change direction by experimenting with gears, wheels and belts, and crankshafts. The session culminates in the design, conceptual drawing, and initial construction of a mechanical toy.

Key Concepts
Simple and compound machines make work easier by multiplying the force we are able to exert. Imagine trying to break a piece of wood apart using your bare hands. Now think how an ax helps you accomplish this task. The ax is a wedge, one of six simple machines.

Machines provide mechanical advantage to make work easier. "Work" is defined as *the application of force to move a load over a distance*.

Work = force x distance

Any machine makes work easier by reducing the force required to move a load. This is known as mechanical advantage. Machines can change the force we exert but not the amount of work done.

Simple Machines
There are six basic or simple machines, which alone or in combination make up most of the mechanical devices we use.

1. **Lever:** A see saw is a lever familiar to everyone. A lever is a stiff rod or plank that rotates around a fixed point, or fulcrum. Downward motion at one end results in upward motion at the other end. Depending on where the fulcrum is located, a lever can multiply either the force applied, or the distance over which the force is applied. There are three kinds of levers, and which kind you have depends on where the fulcrum is set. These are all levers: see saw, wheelbarrow, hammer claw, crowbar, bottle opener, oar, fork, baseball bat, and scissors.

2. **Inclined plane:** The inclined plane can be best described as a ramp or slanted surface, which decreases the amount of force needed to move an object to a higher level. On an inclined plane, the object travels a longer distance, but it takes less force. These are examples of an inclined plane: wheelchair ramp, slide, roller coaster, and escalator.

3. **Wedge:** A wedge is an inclined plane with either one or two sloping sides. It converts motion in one direction into a splitting motion that acts at right angles to the blade. Nearly all cutting machines use the wedge. A lifting machine may use a wedge to get under a load. The following are all examples of wedges: chisel, saw, screwdriver, scissors, door wedge, thumbtack, pin, and nail.

Key Concepts Session 5 (continued)

4. **Screw:** The screw is an inclined plane wrapped around a cylinder. The advantage offered by the screw is that as it turns, rotary motion is converted into a straight motion. This motion can be used to move things apart (as in a car jack), or bring two objects together (a screw drawing two boards together). These devices are screws or have a screw component: jar lid, light bulb, piano stool, clamp, jack, wrench, key ring, and corkscrew.

5. **Wheel and axle:** When a wheel is locked to a central axle, as one is turned the other must turn. A longer motion at the edge of the wheel converts to a shorter more powerful motion at the axle. In reverse, a short, powerful force at the axle will move the wheel's edge a greater distance. The wheel and axle are the basis of these devices: doorknob, roller skates, eggbeaters, manual pencil sharpener, and skateboard.

6. **Pulley:** A single pulley reverses the direction of a force. When two or more pulleys are connected together, they permit a heavy load to be lifted with less force, because the force is spread over a greater distance. Fixtures on flag poles, clotheslines, blinds, cranes, and fan belts all rely on the pulley.

Compound Machines
A compound machine is made of simple machines acting together to perform work. For example, a rotary pencil sharpener is made up of a wedge, and a wheel and axle. Students will see that many mechanical devices are made up of component simple machines when they explore eggbeaters, winged corkscrews, manual can openers, and other everyday household implements.

Compound machines redistribute force with gears, belts, and crankshafts. Energy transfer between components of simple machines is what makes a compound machine work. Gears, belts, and crankshafts are mechanical components that often tie simple machines together, by either transferring a force or changing its direction.

Gear: The common or "spur" gear is a wheel and axle with lever "teeth." When force is applied to the gear, its teeth mesh with those of another gear, transferring the force to that gear. When one gear is larger than another, the turning rate changes. Adjusting relative gear sizes, or gear ratios, gives us a way to change how force is expressed. Anyone who has ridden a bicycle with multiple gears has changed force by adjusting *gear ratios*. Gears can change the direction of a force when their teeth are beveled, or when they are set at an angle to another gear. You can see this change in direction when you observe a rotary eggbeater in action.
Belt: Belts work with wheels and axles to transfer energy. A belt attached between two wheels or shafts transfers force from the one that is powered to the one that is not. A belt can change the direction of a force when the wheels or shafts are set at different angles. It is advantageous to use belts when you want to connect components that are far apart. As with gears, if a belt connects wheels or shafts of different sizes, these will turn at different rates.
Crankshaft: Crankshafts turn rotary (circular) motion into reciprocal (up and down) motion. Students will see how force changes direction when they make their crankshaft toy.

Key Concepts Session 5 (continued)

Potential and Kinetic Energy

Energy can be stored and then released in machines. Stored energy is called potential energy. Released energy is called *kinetic energy*. Think about a windup airplane. When you wind the propeller attached to a rubber band, your human energy is stored as potential energy in the wound rubber band. When you let go, the unwinding rubber band releases energy and powers the plane's propeller.

Friction

Friction is the resistance encountered when one body moves while in contact with another. Friction is the friend and the enemy of machines. In car brakes, friction from the brake shoe pressing against the drum is what causes the vehicle to slow. In this case, friction is an essential function. In other devices, friction causes problems. When component parts meet each other, friction between them can waste energy, produce unwanted heat, and degrade materials. To make machines run well, engineers choose materials carefully and design components to work together efficiently.

More About Simple and Compound Machines

Boston Museum of Science, http://www.mos.org/sln/Leonardo/InventorsToolbox.html*
The Inventor's Toolbox on this site provides information on simple machines.

Science Center, Columbus and Toledo, Ohio,
http://www.cosi.org/onlineExhibits/simpMach/sm1.html*
(Macromedia Flash Player* is required.)
This site is best used as a guided demonstration.

The Franklin Institute, http://sln.fi.edu/qa97/spotlight3/spotlight3.html*
Simple Machines section shows six simple machines in action.

University of Texas,
http://www.engr.utexas.edu/dteach/Experience/mechanisms/brief_overview.htm*
The Mechanisms site is a good review of the concepts of simple machines and mechanics.

Session 5, Activity A

Design, Build, Make It Go!

Goal
Recall and gain experience with motion and energy transfer.

Outcome
Make a rolling toy that travels 3-5 feet (1-1.5 meters) as an introduction to energy transfer.

Description
Students are given a set of materials and challenged to make a toy that rolls 3-5 feet (1-1.5 meters) on its own power. A follow-up discussion about design and students' tinkering experiences past and present help students recall engineering concepts of mechanical engineering. A "recipe" for success is provided so the presenter can make a working version of the rolling toy in advance and later guide the students' efforts.

Supplies
Examples of Stored Energy Toys

- Rubber band airplane, windup toys, paddleball, yo-yo, Slinky*, etc.

One "Rolling Kit" Per Student

- 1 film canister with lid, with holes drilled in both ends
- 2 size #30 or #31 rubber bands (dimensions 2.5" x 1/8" x 1/36" [6.5 cm x 3 mm x 0.7 mm], #31 is slightly heavier)
- 2 washers (either ½" or ¾" [1.25 cm or 2 cm] outside diameter)
- 1 piece of thick drinking straw the length of the canister

Rolling kit

Preparation

1. Bring in stored energy toys to review concepts of potential and kinetic energy.
2. Make holes in the flat ends of the film canisters and lids. The holes can be drilled with 1/4" (0.64 cm) drill bits.
3. Cut drinking straws into lengths. They should be the length of the canister. (You can also use small pieces of a broken pencil if the straw is not strong enough.)

5A: Design, Build, Make It Go! (continued)

4. Place the other materials (2 rubber bands, 2 washers, piece of drinking straw) inside the canister and put the lid on. This is a "design kit."

5. Write the design challenge on the board or poster paper: *Using any or all of the materials in your tiny design kit, make a rolling toy that travels 3-5 feet (1-1.5 meters) on its own power. It does not need to go in a straight line.*

6. Provide measuring tapes or precut lengths of string. Watch a short video clip that demonstrates how to make the rolling toy.

View a Video

Watch a short video clip that demonstrates how to make the rolling toy.

To view the video, select a player and then click on your connection speed.

Select a Player

Dialup High Speed

7. So that you can provide guidance as the students engage in the work, make a rolling toy of your own using the following "recipe" for success (but let the participants design their own varied solutions to the challenge!):

   - Put the rubber band halfway through one washer and thread it back through the loop of the rubber band. Pull on the washer to secure it.
   - Poke the rubber band through the hole in the end of the film canister so the washer is on the outside.
   - Adjust the rubber band so that the washer is flat on the canister.
   - Thread the other end of the rubber band through the hole in the lid and place the lid on the canister.
   - Put the loop of the rubber band through the second washer and then put the end of the straw through the loop. If there is slack in the rubber band, you may need to make a knot above the straw for a snug fit.
   - Adjust the straw so most of the length extends beyond the canister.
   - Turn the straw at least 30 times so the rubber band twists.
   - The second rubber band can be wound onto the non-capped end of the canister, to correct for its smaller circumference.

5A: Design, Build, Make It Go! (continued)

- Put your toy on the floor and let it go! (No one said the toys had to go in a straight line.)

Procedures
Debrief Home Improvement

1. Have students share and compare their lists from *Electric House Hunt* in Session 4.

2. Discuss how electrical units might be incorporated into their projects.

Tinker With Toys

1. Before the students begin the activity, introduce toys that move by storing energy. Lead a demonstration-discussion about stored or potential energy that transfers to kinetic energy as you operate each toy. Ask questions to engage students in a discussion about energy: *Where does the energy to move the toys come from? How is energy stored in these toys? How is energy transferred in the toys in order to make them move?* Remind the students to keep these principles of energy transfer in mind as they begin the design challenge.

2. As students come in, give them each a "rolling kit," direct their attention to the "Rolling Toy Design Challenge" on the board, and challenge them to build their rolling toy.

3. After 15 minutes or so of work time, give participants a 5-minute warning, and then let them demonstrate their toys to one another. (No one said the toys had to go in a straight line.) If they fail to make the toy roll, assure them that there is a method that works, and encourage them to continue trying later.

4. Guide a discussion, asking questions that cause budding engineers to reflect on the design process they just engaged in (successful or not), such as:

   - Is there any one "right" solution for this challenge? Why or why not?
   - What would you do differently if you had more time? Different materials?
   - Can anyone tell about their process; when and why they might have switched to a new idea?
   - What did you learn from watching each other?
   - It is said you have to have a breakdown before a breakthrough. Can anyone relate to that?

Develop Concepts

1. Develop the concept of energy transfer: Tell student pairs to discuss how the toy is powered and be ready with an agreed-upon explanation for the group. Have them report, and probe for answers to these questions:

5A: Design, Build, Make It Go! (continued)

- Where does the energy come from, and where does it go?
- At what point is energy transferred from you to the toy?
- At what point does potential (stored) energy change to kinetic (released) energy?
- Is this a machine?

Wrap Up

Explain that many devices are made up of mechanical component parts that transform energy in order to perform work. The next activities will give students more experience with moving parts. They may want to include moving parts in their personal design projects later on.

Have students read and then discuss *5A Reading: Slinky*.

Follow With

In *5B: Not-So-Simple Machines*, students study simple machine examples from everyday life.

The definitions of work and mechanical advantage are developed, and students participate in a design challenge involving simple machines.

Design, Build, Make It Go!

Handout: Session 5, Activity A

Make a Rolling Toy Design Challenge: Using any or all of the materials in your kit, make a rolling toy that travels 3-5 feet (1-1.5 meters) on its own power. (It does not need to go in a straight line.)

If you get stuck along the way, here are some hints:

- Consider a windup toy. How does it work? Take a look at some toys that store and release energy to produce some kind of motion.
- Windup toys convert potential energy into kinetic energy as they unwind.
- How is the energy stored and released? (Often this is a spring.)
- What could be used instead of springs to store and release energy?

Slinky

Reading: Session 5, Activity A

Patented by Richard James, Upper Darby, Pennsylvania for James Industries. Filed 1 November 1945 and published as GB 630702 and US 2415012.

This is the familiar toy which consists of coils that move downstairs, along the floor, or from hand to hand. Richard James was a mechanical engineer working for the U.S. Navy. While he was on a ship undergoing trials, a lurch caused a torsion spring to fall accidentally from a table to the floor. Its springy movement made him think. When he saw his wife Betty that night he showed her the spring and said, "I think there might be a toy in this." Two years of experimentation followed to achieve the right tension, wire width, and diameter. The result was a steel coil with a pleasant feeling when handheld, with an ability to creep like a caterpillar down inclined planes or stairs, and an interesting action when propelled along the floor. Betty came up with the name of Slinky*, from slithering.

James managed to persuade Gimbels, the department store, to give him some space at the end of a counter. He would demonstrate the toy and hope to sell some of his stock of 400. It was a miserable November night, and Betty and a friend were on hand to buy a couple to encourage sales. They never had the chance, as crowds gathered around and the entire stock went in an hour and a half. A company, James Industries, was set up to make the product. A machine was devised which coiled 24 meters in 10 seconds. The price for a Slinky was $1 in 1945, which had increased to $2 by 1994. More than 250 million have been made, with some variations, including brightly colored plastic models. The only substantial change in the design is that the end wires are now joined together to prevent loose wires damaging, for example, an eye. The trademark was registered in the United States in 1947 and in Britain in 1946.

Besides the obvious fun possibilities, the toy has been used by science teachers to demonstrate the properties of waves. NASA has used them to carry out zero gravity physics experiments in the space shuttle. And in Vietnam, American troops used them as mobile radio antennae.

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Van Dulken, Stephen. *Inventing the 20th Century, 100 Inventions That Shaped the World*. New York: New York University Press, May 2002. www.nyupress.nyu.edu*

Session 5, Activity B
Not-So-Simple Machines

Goal
Reinforce concepts about simple machines.

Outcome
Students identify the six types of simple machines found in everyday objects and participate in a challenge to see how machines aid work by providing mechanical advantage. Students understand that it may take more than one simple machine to perform a task (creating a compound machine).

Description
Students study simple machine examples from everyday life. The definitions of work and mechanical advantage are developed, and young engineers participate in a design challenge to see how simple machines operate as component parts of more complex machines. A final discussion sets the stage for the next activity, where moving parts are explored.

Supplies
Simple Machine Examples

- Wedge: chisel, saw, screwdriver, scissors, door wedge, thumbtack, pins
- Wheel and axle: doorknob, roller skates, eggbeaters, pencil sharpener, skateboard
- Screw: nuts and bolts, jar lid, lightbulb, key rings, corkscrew
- Pulley: flagpoles, clotheslines, blinds, crane, fan belt
- Lever: see saw, wheelbarrow, hammer, crowbar, bottle opener, oar, fork, baseball bat
- Inclined plane: wheelchair ramp, slide, hill, roller coaster, escalator

Simple Machine Challenge

- 1 washer (either ½" or ¾" [1.25 cm or 2 cm] outside diameter) per group
- 1 plastic or paper cup per group
- Meter sticks
- Brads, clay or play-dough, clothespins, craft glue, craft sticks, dowels, drinking straws, foam pieces, gears, hot glue, magnets, paper clips, pipe cleaners, plastic bags, plastic spoons, plastic/paper cups, pulleys, rope, rubber bands, scissors, spools, springs, string, tape, wire

Preparation

1. Learn about simple machines.

    - Simple machines help us do work. You are doing work when you use force to cause motion. When you exert a force (such as pushing or pulling) on an object over a distance you are doing work. Simple machines make work easier by lowering the effort required to move an object or by increasing the distance an object moves. Work = Force x Distance.

5B: Not-So-Simple Machines (continued)

- Simple machines provide a mechanical advantage when the machine puts out more force than is put in. An automobile jack shows a good example of mechanical advantage. The relatively small amount of force a person applies to the handle produces a large enough force to lift a heavy automobile. The automobile jack exhibits mechanical advantage.

2. Prepare a *short* demonstration of simple machines using a Web site. If time allows, view the COSI Science Center Web site (www.cosi.org/onlineExhibits/simpMach/sm1.html*) as an introductory presentation with your students. Allow about 10 minutes to go over the main concepts. Prepare for the presentation by following the steps below:

    - Spend time at the site and browse through all the pages you'll use.
    - Connect a projection device to one networked computer for presentation on a screen or blank wall.
    - Browse all the pages you'll be using in advance so they will be cached in the computer (this reduces load time during the presentation).

Presentation

1. At *The Essence of Simple Machines*, move the cursor over the simple machines, and watch them work. Notice that all of them have a force applied to them to complete work. Click on each machine and watch it go. During the tour of the Web site, highlight the definitions of work and mechanical advantage.

2. Return to the home page and click at the left and right links (in red) to learn about machines, work, and mechanical advantage. Ask students to give an example of how simple machines make work easier.

3. At the home page, go to the bottom link, *Find the Simple Machine*. Follow the directions and see if the students can spot all the machines in a lawnmower.

Procedures

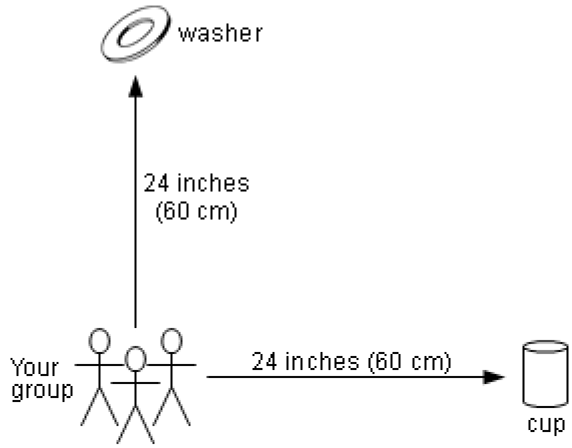
1. In a whole group discussion, demonstrate and define some basic terms—work, simple machines, and mechanical advantage—while showing examples of simple machines. (As an option, you may also bring in pictures of people using simple machines for the purpose of this review.) Ask students to sort the examples into the six simple machine categories: wedge, wheel and axle, screw, pulley, lever, inclined plane.

2. Keep the examples of simple machines sorted on a table so students can refer to them during their design challenge. Next, arrange students into groups of at least three to complete the simple machine design challenge.

5B: Not-So-Simple Machines (continued)

Design Challenge

Using at least one simple machine, design and construct a device that can move a washer that is placed 24 inches (60 cm) away from your group, 90 degrees, to a cup that is also placed 24 inches (60 cm) away. See diagram below:



Design Requirements

- Each group must use at least one simple machine in the device they build.
- The washer must be moved from its location to the fixed location of the cup without direct contact from any student.

Think about:

- What process will you go through in order to design a solution?
- Which simple machines can be used to solve the problem?
- What process will you go through in order to design a solution?

5B: Not-So-Simple Machines (continued)

Materials

Brads	Plastic bags
Clay or play-dough	Plastic spoons
Clothespins	Plastic/paper cups
Craft glue	Pulleys
Craft sticks	Rope
Dowels	Rubber bands
Drinking straws	Scissors
Foam pieces	Spools
Gears	Springs
Hot glue	String
Magnets	Tape
Paper clips	Wire
Pipe cleaners	

Have students share their solutions. While students are sharing, ask questions that cause students to reflect on the design challenge they just engaged in. Get students to discuss some of the key concepts in this session (work, mechanical advantage, compound machines) and how those concepts are related to their design solution.

Some questions you might ask:

- What simple machines did you use?
- Was your device made up of more than one machine?
- How did using a simple machine give you a mechanical advantage?
- How did the use of simple machines make the work easier to complete?

Supplementary Information
Simple machine sites:

- Inventor's Toolbox: The Elements of Machines:
  www.mos.org/sln/Leonardo/InventorsToolbox.html*
  and the page it links to: Gadget Anatomy:
  www.mos.org/sln/Leonardo/GadgetAnatomy.html*

- Edheads Simple Machines: http://edheads.org/activities/simple-machines

5B: Not-So-Simple Machines (continued)

Wrap Up
Discuss ways students might use simple machines in inventions. Challenge kids to find the mechanical action in the moving parts they'll use in the next activity.

Have students read and then discuss *5B Reading: Meet a Mechanical Engineer.*

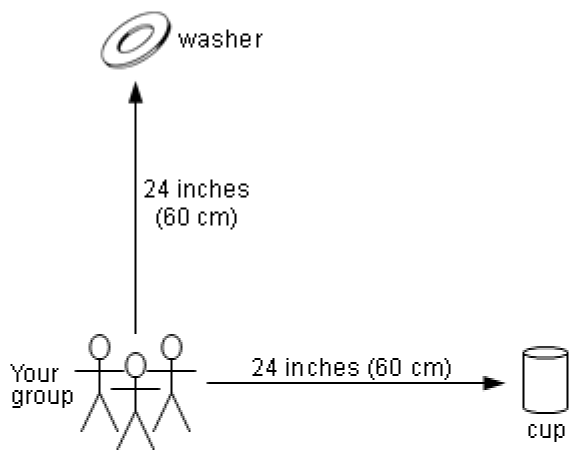
Follow With
In *5C: Gears, Cranks, Crankshafts, and Belts*, students put moving mechanical parts to work. Collect a variety of mechanical devices that have visible moving parts (for example: eggbeaters and hand drills), enough for one device per group of three students. Consider asking students to bring devices from home in preparation for this activity.

Not-So-Simple Machines

Handout: Session 5, Activity B

Use what you know about simple machines to create a solution to the following design challenge.

Design Challenge
Using at least one simple machine, design and construct a device that can move a washer that is placed 24 inches (60 cm) away from your group, 90 degrees, to a cup that is also placed 24 inches (60 cm) away. See diagram below:



Design Requirements

- Each group must use at least one simple machine in the device they build.
- The washer must be moved from its location to the fixed location of the cup without direct contact from any student.
- You may use only the materials provided.

As you go through the design process, think about:

1. What problem is being solved?
2. Which simple machines can be used to solve the problem?
3. What process will you go through in order to design a solution?

Be prepared to share your design solution.

Meet a Mechanical Engineer

Reading: Session 5, Activity B

Alma Martinez Fallon
Northrop Grumman Newport News

Mechanical engineers help to shape nearly everything in the built environment, but their impact on communities isn't always visible. "Anything that moves, heats, cools, rotates, or flies, there's a mechanical engineer involved in it," says Alma Martinez Fallon. She engineered mechanical systems in support of nuclear submarines and aircraft carrier design before moving into management ranks at one of the nation's largest shipbuilders, Northrop Grumman Newport News. Although mechanical engineers are involved in the design and production of everything from cars to power plants to refrigerators, she adds, "the only time most people hear about engineers is if something fails."

As president of the Society of Women Engineers and an active member of the American Society of Mechanical Engineers, Fallon is helping to make sure that more young people know what engineers do and why the field offers a world of opportunities.

How She Got Interested

Fallon excelled at mathematics through high school, "but I didn't know where I could apply my skills, other than to teach." She didn't know any engineers in her neighborhood of Queens, New York, where her parents settled after immigrating from the Dominican Republic. And she didn't want to be a teacher.

Fallon says she took a "nontraditional path" into her profession. She worked full-time after high school and didn't return to college until age 25. By then, she had met some professional engineers who encouraged her to apply her interest and aptitude in math to an engineering degree.

At Old Dominion University in Norfolk, Virginia, she was one of a handful of women in her engineering classes. She was drawn in by the subject, as well as the chance to "give back to the community. Engineering touches everything. It's been a great fit for me," she says. "I like the practical side of applying math and science to problem solving. I was hooked right away."

5B Reading: Meet a Mechanical Engineer (continued)

Entering the Profession
To help pay the bills during college, Fallon took advantage of an opportunity to combine her studies with work experience. While still an engineering student, she began to learn about shipbuilding design and construction. The practical experiences shaped her course selection, and she decided to focus her undergraduate studies on mechanical engineering. When she graduated, Newport News offered her a position as an associate engineer, working on the design and engineering of *Seawolf* class submarines.

Before long, Fallon was discovering what many mechanical engineers find rewarding about their work. "Designing something and seeing it work—getting to see it run on a ship—that's a lot of fun," she says. Fallon's initial plan was to stay at the company for a few years to gain a solid technical foundation. Instead, she found herself moving up through the engineering ranks and into management. She also expanded her skills by earning a master's degree in engineering management from George Washington University. Now a 15-year veteran of Newport News, she manages a group of about 100 engineers, planners, and analysts involved in planning and manufacturing engineering.

Applying Diverse Skills
As a manager, Fallon draws on a wide range of skills, not all of them taught in engineering school. "You have to be able to communicate, to be strategic, to motivate people. You have to help excite the organization, move the goals and objectives forward, and provide results. It's different from what an engineer learns in school," she admits, "but I use my engineering training to work through the organization as a leader."

What does she like best? "The ability to develop people, to help them grow as individuals. That's number one. Also, I'm results oriented. My area can take on a difficult problem, and seeing it through to resolution and implementation can be very rewarding."

Advice for Students
For students thinking about a future in engineering, Fallon has some specific advice: "Stick to your math and science." In addition, she suggests looking for "programs outside of class that can expose you to career choices in the area of math and science." In her own career, she can see the value of mentors. "During my time at Newport News, I have found individuals who have taken an interest in supporting me." Now she has moved into the mentor role, helping young engineers as they enter the profession. Today's students can take advantage of online opportunities, she adds, no matter where they live. "Through e-mentoring, you can find a mentor who's interested in helping you."

The future looks bright for students who pursue mechanical engineering as a career, Fallon says. "Demands of the workplace continue to increase, especially as technology continues to be enhanced," she says. "Anything that moves, anything that involves heating or cooling, anything that generates power, there's a need for mechanical engineers to design and produce

5B Reading: Meet a Mechanical Engineer (continued)

it. The demand is going to be there."

In her role as president of the Society of Women Engineers, Fallon is an advocate for improving the number of women entering the field. Although women account for only about 20 percent of engineering school graduates, "some universities are doing very well. We want to understand why," Fallon says, and then find ways to build on that success.

Session 5, Activity C
Gears, Cranks, Crankshafts, and Belts

Goal
Study moving machine parts to learn how force can be transferred or change direction to accomplish work.

Outcome
Make a crankshaft mechanism and use it with other parts in a unique mechanical toy.

Description
After an introduction to the moving parts of machines (gears, cranks, crankshafts, belts, and wheels), students investigate these parts and make a crankshaft mechanism. Students begin work on a mechanical toy of their own design. They complete work on the toy at home.

Supplies
Optional Mechanical Parts

- Gears set
- Wheels set
- 1/4"-wide rubber band "belts" (size #64)
- Small wooden dowels (Bamboo skewers will work.)

One Crankshaft Kit Per Student

- Small box (8 oz. milk carton will do)
- 3 pieces 16-gauge steel wire: one 8" (20 cm) length, two 3" (7.5 cm) lengths
- 1 straw
- Electrical tape or long bead (for crank handle)
- Several pairs of needle-nose pliers

Other

- Tools that use moving parts: eggbeaters, hand drills, winged corkscrews, flour sifters, ice cream scoopers, nut grinders, and manual can openers
- Miscellaneous gears, belts and wheels, wire, art supplies, and other materials of choice
- Crankshaft model (see below)

Preparation

1. Collect a variety of mechanical devices that have visible moving parts (example: eggbeaters, hand drills), enough for one device per group of three students. A mounted

5C: Gear, Cranks, Crankshafts, and Belts (continued)

manual pencil sharpener in the room (cover removed) can serve as one device. (Consider asking students to bring devices from home at the end of the previous day.)

2. Collect tools, including needle-nose pliers, rulers or measuring tapes, and scissors.

3. Prepare a model crankshaft in a box. See *5C Handout: Gears, Cranks, Crankshafts, and Belts*.

> **View a Video**
>
> Watch a short video clip that demonstrates how to make the crankshaft toy.
> Select a player and then click on your connection speed.
>
> To view the video, select a player and then click on your connection speed.
>
> Select a Player
>
> Dialup High Speed

Procedures

Exploration: Look at Moving Parts

1. Distribute a variety of mechanical devices (egg beaters, etc.) that have visible moving parts, one to each group of three students. Ask these questions, and have each team answer and demonstrate:

   - Can you count the moving parts?
   - How do the moving parts connect to one another?
   - Can you name any of the moving parts (crank, gear, moving shaft, blade, spring)?
   - Can you find places where the force or motion changes direction? (Example: corkscrew wings press *down* causing the cork to pull *up*.)
   - Demonstrate how the device operates to perform work.

2. Introduce the concept of "mechanism." A mechanism is a set of moving parts that changes the direction of a force or motion. The next three component sets act as mechanisms.

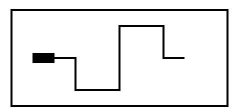
5C: Gear, Cranks, Crankshafts, and Belts (continued)

- Optional: Set out an array of connecting gears of different sizes, and show students how the direction of a force can be changed when they are flat or connected at the 45-degree bevel. Use skewers as cranks. Challenge students to find the relationship between the size of the gears and the relative number of times one turns another. Note: a single speed bicycle could be used instead.
- Ask: How many times does the small green one turn when the large red one turns around once? (A large gear might turn once, turning a smaller gear three or more times. This is the gear ratio.)

3. Demonstrate belts and wheels and how one wheel can turn another: With the help of a student assistant, put axles (such as a pencil) through two wheels, and connect the wheels with a rubber band "belt." Point out that one wheel is the drive wheel, and turning it causes the other wheel to move, by force of the turning belt. Ask:

    - Where have you seen wheels and belts in action (fan belt in car, conveyor belt on the grocery store checkout counter)?
    - What if a large wheel and belt turned a small wheel (recall ratios, as with gears)?

4. Introduce the crankshaft by showing a wire crankshaft made from a paper clip bent into the shape shown. Show how a crankshaft changes the direction of a motion from rotary to reciprocal.



5. Give students 10-15 minutes to investigate the components. Encourage them to consider using these parts in combination in mechanical devices they might make.

Construction

1. Make the crankshaft device, following directions on the handout. Students should take this basic device home and turn it into an appealing toy.

2. Have students engage in a short planning activity before they go home.

Wrap Up
Allow at least 30 minutes to get ready for the Home Improvement activity. Introduce the Home Improvement design challenge, and complete steps 1-5. Have designers present their toy ideas to the group for feedback. Direct them to take their materials home and finish their toy. The journal notes and sketches will be helpful for communicating their ideas to family members who can help.

Follow With
In Session 6, *One Problem, Many Solutions*, students consider the many designs of clock radios, and see how electrical and mechanical components make clocks tick.

Gears, Cranks, Crankshafts, and Belts

Handout: Session 5, Activity C

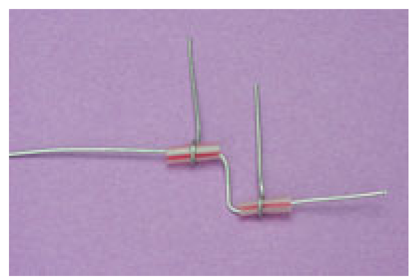
Make a Crankshaft Device

Do you remember playing with jack-in-the-box toys when you were small? They have a crank mechanism something like the toy you will make today. With this crankshaft toy, you will see how the direction of a force can be changed mechanically. Turning the crank around and around makes other parts go up and down!

Supplies

- Small box (8 oz. milk carton will do)
- 3 pieces 16-gauge steel wire: one 8" (20 cm) length, two 3" (7.5 cm) lengths
- 1 straw
- Electrical tape or long bead (for crank handle)
- Needle-nose pliers

Steps



1. Cut off the top of a milk carton to make a small box with one side open.

2. Turn the box so the opening is on the table, and drill or poke a hole toward the top third of the box at the same height on opposite sides.

3. Drill or poke two holes in the top, about an inch or 2 1/2 centimeters apart. They should be in a straight line with the other two holes.

4. Cut two short pieces of straw about 1/3 the width of the box.

5. Wrap the end of one of the small pieces of wire around one piece of straw. Tighten the wire so that it pinches the straw while allowing for another wire to pass through. Repeat with the other wire and straw.

6. Take the long wire; make two 90-degree bends, an inch or 2 ½ centimeters apart, leaving one side slightly longer than the other. The longer end becomes the crank handle.

7. Thread a straw with wire attached onto each end of the wire to the bend.

8. At the outside of each straw, make another 90-degree bend, making a “U” with the center section.

9. Find the halfway point of the center section of wire between the straws. Using this as a guide, bend the outer wires away from the center at that point.

5C Handout: Gears, Cranks, Crankshafts and Belts (continued)

10. From the inside of the box, place the crack handle end of the wire through one of the side holes.

11. Reach into the underside of the box and gently turn the smaller wires so they poke through the holes in the top of the box.

12. Place the other end of the wire into the other hole. You may need to bend this and then re-straighten. Make a bend in the wire to secure it on the outside of the box.

13. Bend the crankshaft end to make a handle. Secure a large bead or electrical tape on the crank to finish the handle.

Crank the handle and watch the wires go up and down. It may need some adjustment to get the best motion. Now it's all up to you! How will you turn the up-and-down motion into something fun?

Design A Mechanical Toy

Session 5, Home Improvement

Goal
Discover ways to use moving parts, and get ready to make a unique mechanical toy at home.

Description
Students use the crankshaft mechanism that they built in the previous activity as the basis for a mechanical toy. They should sketch out details of the design, jot down notes, and then finish the toy at home.

During the Session
Complete steps 1-5 before inventors go home:

1. Ask students to consider what they'd like their mechanical toy to do. Have them make concept drawings in their journal to show what the toy might look like when completed. Encourage them to make a series of sketches; this is a thinking step.

2. Instruct them to describe their toy's function (what they'd like it to do) and then its form (finished toy and component parts).

3. Encourage them to keep drawing and writing and revising—these steps will help them refine their plan.

4. Tell them to use their writing and drawing to explain their plan to a friend and the facilitator.

5. Make changes as needed, collect materials, and begin!

At Home

1. Spend time fine-tuning the device so it works reliably.

2. Add fun elements to turn it into an eye-grabbing plaything.

3. Bring it in the next day for everyone to enjoy!

Examples of toys: jack-in-the-box, two dancers or acrobats, articulated animal (one cloth sleeve covers both wires to cause a rocking motion effect), wacky wires (twist top wires into spirals, thread beads onto them for an up-and-down motion).

Design A Mechanical Toy

Handout: Session 5, Home Improvement

Your mechanical toy can be as unique as you want it to be. Spend some time planning the toy and then finish making the toy at home. Plan your mechanical toy in your design notebook.

1. Describe your toy's function. What would you like it to do? How will it do this?
2. Draw your plans for your mechanical toy.
3. Spend time fine-tuning the device so it works reliably.
4. Add fun elements to turn it into an eye-grabbing plaything.
5. Bring it in the next day for everyone to enjoy!