THE FRANKLIN INSTITUTE

amazing MACHINE

K–12 Educator's Guide

Amazing Machine Educator's Guide

AMAZING MACHINE invites students to explore the science and art of machines. The classroom activities presented here in this guide could be used in preparation for a visit to the exhibit or as extension activities after returning to school. Either way, students will be able to connect the activities with their experience in the exhibit.

A visit to "Amazing Machine" provides an opportunity to engage students with concepts that support standards-based learning in both science and social studies.

How to Prepare

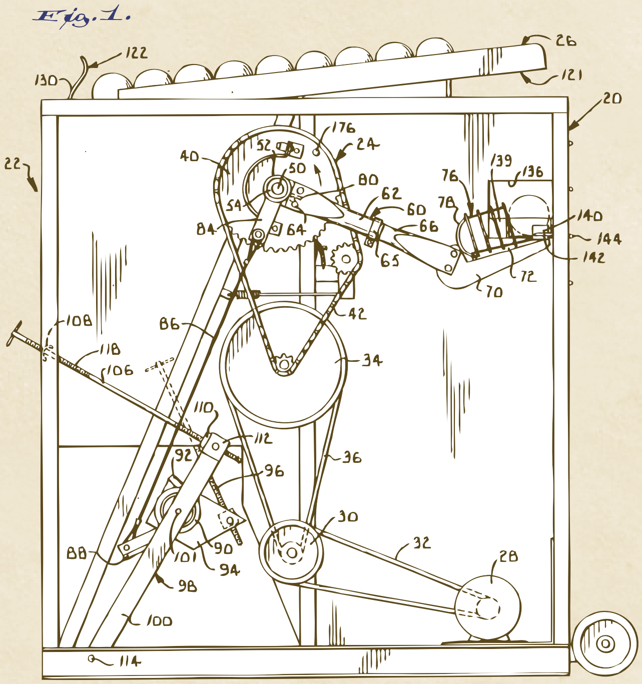
The "big idea" in **AMAZING MACHINE** is the simple beauty of machines. Encourage your students to look for the science, but also to notice the elegant beauty of the mechanical devices they'll see in the exhibit. If they do both, they'll leave the exhibit with a deeper appreciation of what machines are and how they work.

During the week before your visit, invite your students to brainstorm a list of machines that they use throughout the course of their day. Assemble the list on chart paper and save it for after their visit. Then, have students decide how many of the machines on their list work on principles they saw in the exhibit. Most will.

Educational Goals

- Students will understand that machines are a controlled system of components that transmit or modify energy to perform a task.
- Students will explore the universal components—gears, springs, cams, pulleys, linkages, and screws—that make up machines.
- Students will recognize that different principles of control—on/off, speed/rate, and sequence—are needed to use machines effectively.
- Students will learn that machines convert and transform energy—electrical, fluid, chemical, and heat—into mechanical motion.

Fig. 1.



Quick Tips

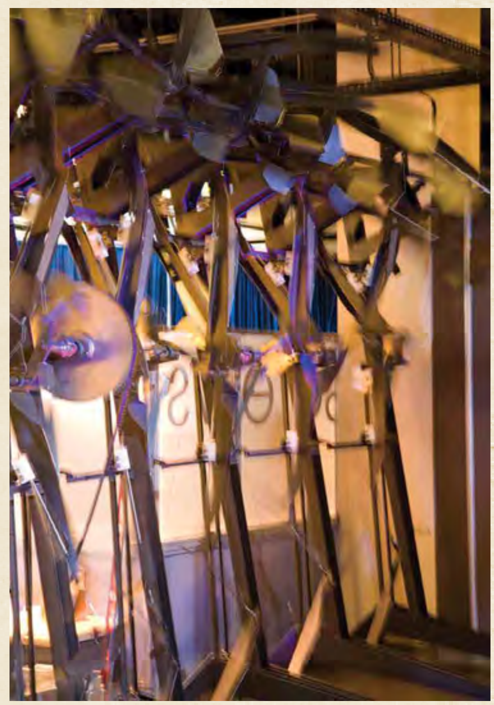
- The 4,500 square-foot exhibit is located in the Mandell Center, accessed via the main Atrium on the Second Floor. The entrance is to the right of the Sci-Store, near the IMAX Theater.
- The exhibit has three thematic areas: universal components, control, and power.
- The learning experience is greatest when students engage with the numerous interactive devices scattered throughout the exhibit. For logistical reasons, however, you might recommend that students work in small groups in order to enable everyone to use all of the devices.
- There is a staircase in the far corner of the exhibit that leads up to the special exhibit gallery. Alert your students that they are not to use that staircase. Otherwise, the only exit from the exhibit is the same ramp/walkway you use to enter.
- The exhibit is located beside the Sci-Store. As you enter the exhibit, students will see glass doors leading from the store. They are clearly marked with a sign that says "Not an Entrance." Still, some students may be tempted to enter the store via those doors.
- On average, most groups will spend about 30-40 minutes in the exhibit.

What to Expect

The exhibit is organized in three thematic areas representing concepts behind how machines work: universal components (focusing on gears, springs, cams, pulleys, linkages, and screws), control (focusing on rate, on/off, and sequence), and power (focusing on chemical, electrical, and fluid energy). Within each thematic area, you'll find a mix of interactive devices and real machines. Each area is separate but within an open floor plan, allowing you to move among the concepts and see that they are inter-related.

WHILE YOU AND YOUR STUDENTS VISIT THE EXHIBIT, YOU WILL SEE:

- "Skinned" and "exploded" machines which have had their outer casing removed so that you can see what happens inside;
- Three amazing mechanical sculptures which reveal the awesome beauty of machines;
- Significant historical artifacts from The Franklin Institute's collection of mechanical devices including the Patent Models, Automaton, and clock mechanisms.



WHEN YOU AND YOUR STUDENTS LEAVE THE EXHIBIT, YOU WILL UNDERSTAND HOW:

- Machines are made up of systems of components;
- Machines have many or all of the universal components working together;
- Each component has its own qualities, yet together they create something more than a mere sum of the parts.

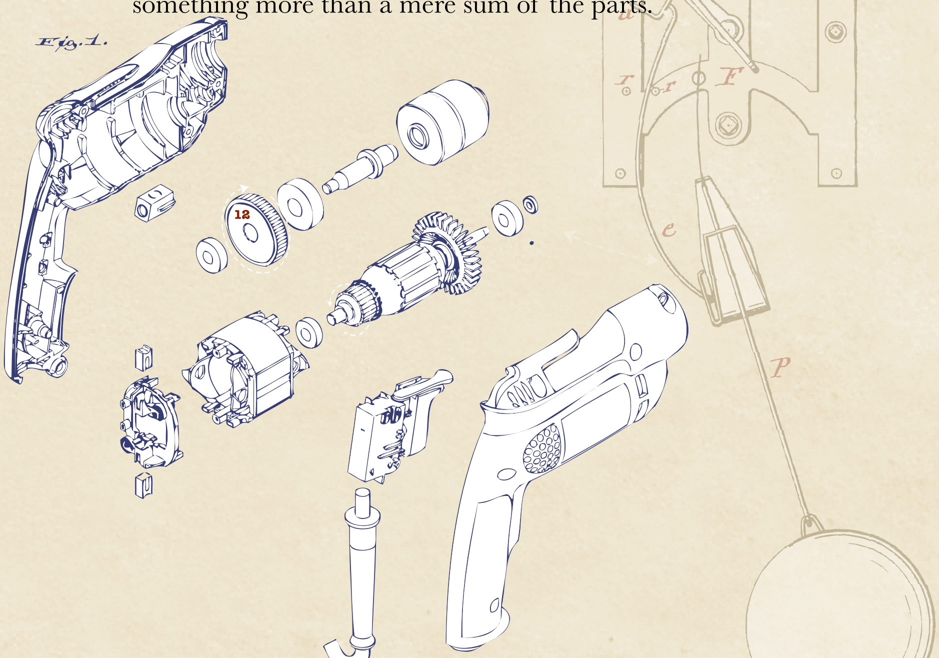
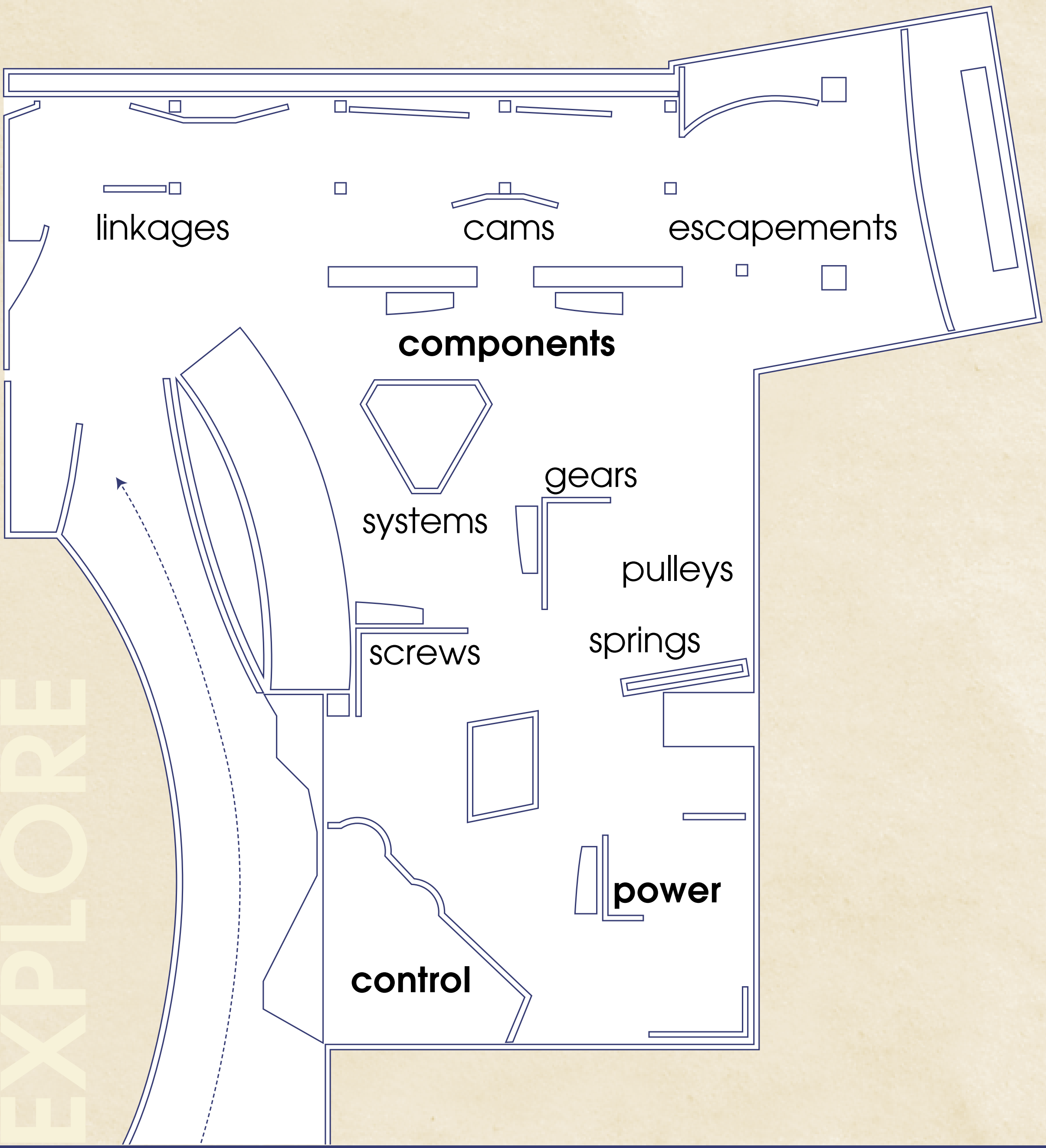


Exhibit Areas

As you move through the exhibit's physical space, you will find devices and historical machines grouped according to the three themes. The following overview of the arrangement will help you plan your time in the exhibit.

ENTRANCE/ORIENTATION

The entrance to the exhibit is a downward sloping corridor that invites you into the space below. Along one side of the corridor is a display of Patent Models from The Franklin Institute's historical collection. At the bottom of the ramp, the first of the three kinetic sculptures greets you at the main entrance to the exhibit.



EXPLORE

Exhibit Areas

UNIVERSAL COMPONENTS

universal components

Machines are made up of groupings of components.

As you turn the corner and enter the main area of the exhibit, you'll be in the thematic area related to universal components: linkages, cams, gear, springs, pulleys, and screws. Within this area, you'll encounter devices related to each component.

LINKAGES are the joints in a machine that transfer, amplify, or change motion.

Wave the Flag – Turn a crank in a full circle that, through the linkage, waves a flag. The linkage converts circular motion to reciprocating motion.

Swing the Hammer – Move a handle with a limited range of motion. Through a set of linkages, the motion is amplified and a hammer at the opposite end swings in a large arc.

Ring the Bell – Push up and down on a handle and, through linkages, ring a bell at the opposite end.

CAMS are rotating disks, shaped to convert circular into linear motion.

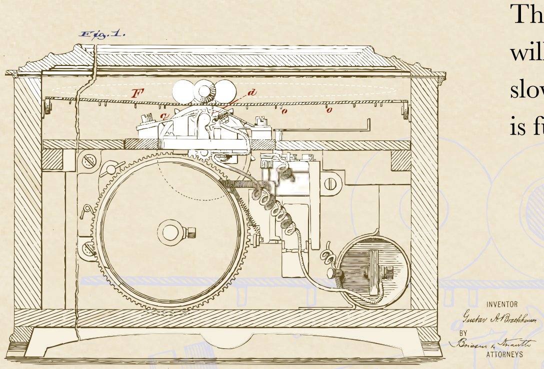
Timing Is Everything – Rotating cams will open and close gates along a ramp. Watch carefully and then release the ball to roll down the ramp without being stopped by any of the gates.

Cams Make Music – Position the two cams correctly and you'll hear the familiar "Happy Birthday" melody. If the cams are out of synch, the melody won't make sense.

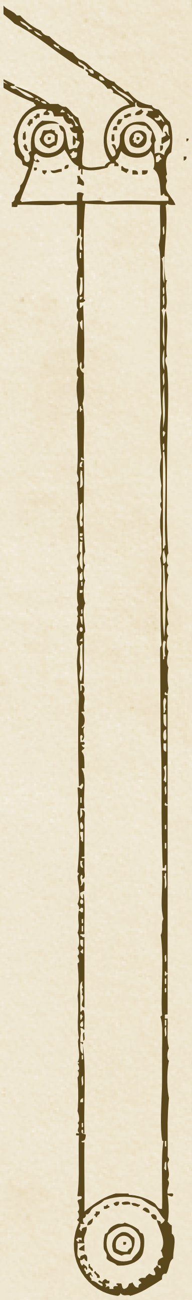
A **GEAR** is a toothed mechanical part that engages with similar toothed parts to transmit motion from one rotating body to another.

Gear Speed – Measure the speed of each gear by turning one master crank. Notice the relationship between gear size and gear speed.

Can Crusher – Join the can crusher club! Throughout the course of a week, many visitors will turn the crank and activate a gear train that slowly crushes a metal trash can. Once the can is fully compacted, a new can is put in its place.



universal components



A **SPRING** is a resilient metal coil that reverts rapidly to its original position after being extended, compressed, or tensed.

Look inside machines for springs which can store potential energy for later use as kinetic energy.

A **PULLEY** is a kind of wheel and axle which is used to distribute power within a machine.

Pulleys Distribute Power – Stretch the belts from wheel to wheel and create your own unique power distribution grid. See how the placement of your belts creates a pulley system that moves energy throughout the machine.

A **SCREW** is an inclined plane wrapped around a cylinder, used to turn circular motion into linear motion.

Screw Lift – Each circular turn of the Archimedes screw moves the ball forward in a linear motion.

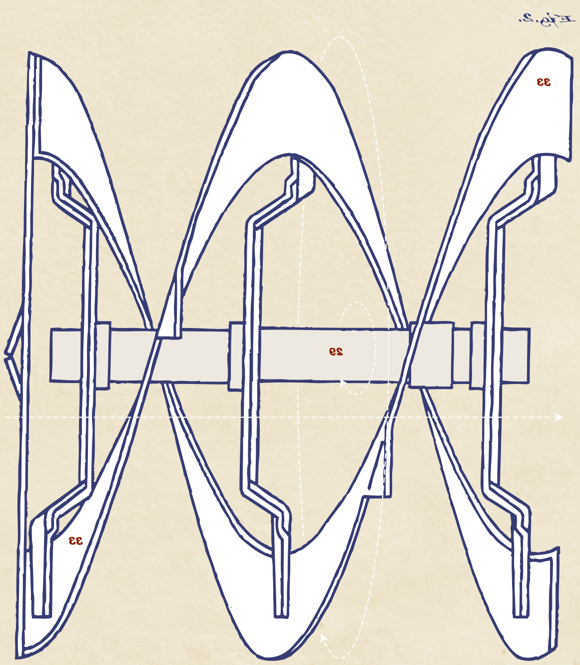


Exhibit Areas

CONTROL

Different methods of controlling machines are needed to operate machines effectively.

The second thematic area is control. The content in this area suggests that the principles of control are necessary to operate machines effectively and control the outcome. Solving the control challenges was the most important step in the process of industrialization. Without control, we would have little use for machines, no matter how beautiful and powerful they might be.

Stamp in Time – Synchronize the motion of the conveyor belt and the stamping bar. When this control challenge was mastered, mass production via conveyor belts changed American industry.

Sequence for Control – Coordinate the movement of the parts of the mechanical arm and move the blocks from place to place. You'll recognize this device as a giant crane, the origin of which made skyscrapers and other manufactured landscapes possible.

On/Off Controls – Switch the power flow to control the tilt of a disc and move the ball through the maze. Beware! This challenge is very difficult, but once you get the hang of the switching you'll have reached the target and mastered an industrial processing technique—one that is essential in the field of robotics today.

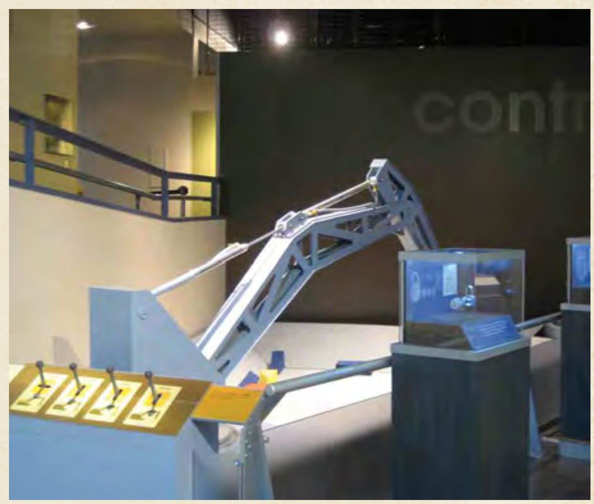


Fig. 1.

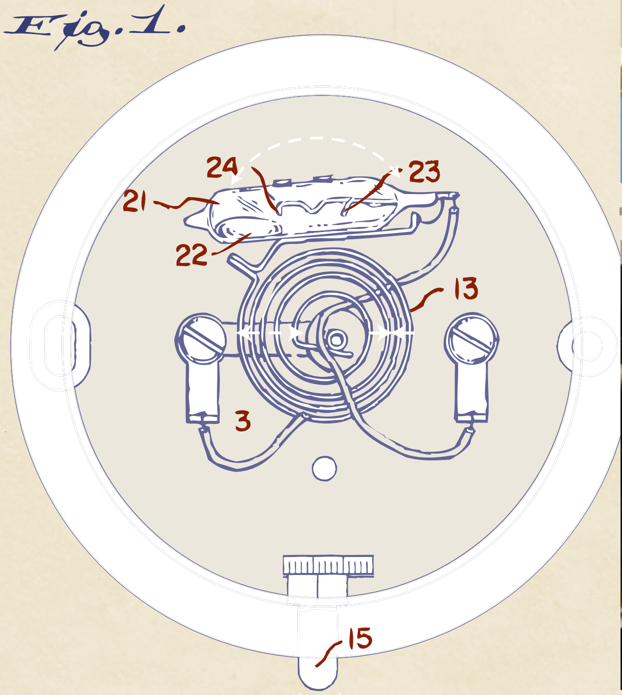


Exhibit Areas

POWER

Machines convert energy into mechanical motion.

The third thematic area is power. When machines operate properly, energy transformation results, empowering our lives. Different kinds of energy can react to spark the mechanical motion that produces power. The devices in this area explore those different possibilities.

Make a Motor – Magnetic energy and copper meet to create a rapidly spinning coil.

Rocket Launcher – Air pressure can be controlled to power a "rocket" along a guide wire. Too much pressure and the rocket overshoots its target; too little and it falls flat.

Internal Combustion Engine – What's happening under the hood? Most cars rely on internal combustion engines for power. Look inside and see how the parts all work together as you scroll through digital images from inside the engine.

Air Power – Wind energy is plentiful and powerful. Plug in the four devices (anemometer, horizontal windmill, squirrel cage blower, and pneumatic tool) and see how wind energy powers their motion.

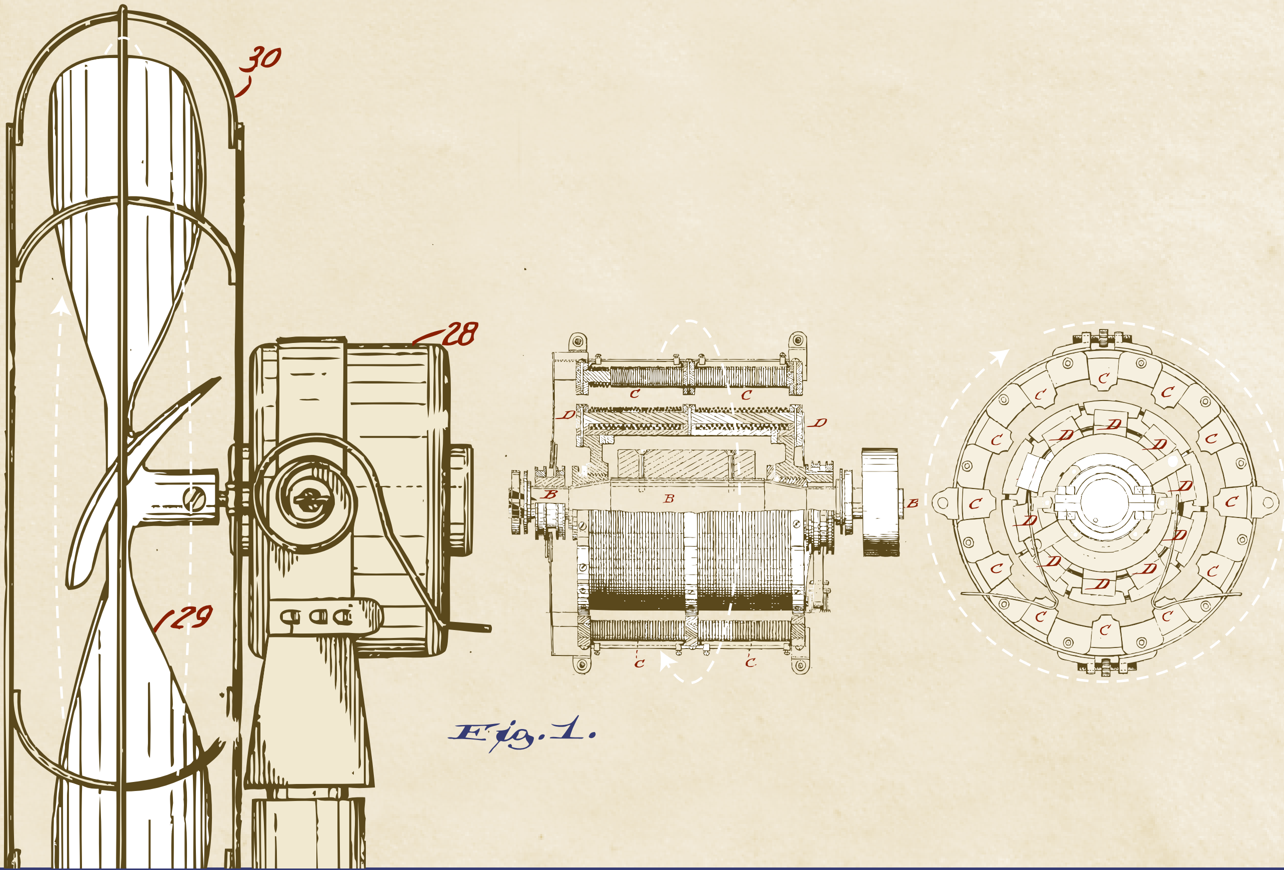


Fig. 1.

Maillardet's Automaton

Nestled in a glass case within the wall between the universal components and control areas is an amazing example of the elegance of machines.

In 1928, The Franklin Institute accepted the donation of a damaged but interesting mechanical device about which no one knew much. The Institute's curators and technicians set about restoring the device in an attempt to see what they had. Once the gears were cleaned and primed, the Automaton came to life and told its secret! It lowered its head, positioned its pen, and began to produce elaborate sketches. Four drawings and three poems later, in the border surrounding the final poem, the Automaton clearly wrote, "Ecrit par L'Automate de Maillardet." This translates to "Written by the Automaton of Maillardet." Amazingly, the first clue of the true history and identity of the machine had come from its own mechanical memory!

Henri Maillardet was a Swiss mechanician of the 18th century who worked in London producing clocks and other mechanisms. It is believed that Maillardet built this Automaton around 1800. He made only one other Automaton that could write; it wrote in Chinese and was made for the Emperor of China as a gift from King George III of England.

The Franklin Institute's Automaton has the largest "memory" of any such machine ever constructed—four drawings and three poems (two in French and one in English). Maillardet achieved this by placing the driving machinery in a large chest that forms the base of the machine, rather than in the Automaton's body.

The memory is contained in the cams (brass disks). As the cams are turned by the clockwork motor, three steel fingers follow their irregular edges. The fingers translate the movements of the cams into side to side, front and back, and up and down movements of the doll's writing hand through a complex system of levers and rods that produce the markings on paper.

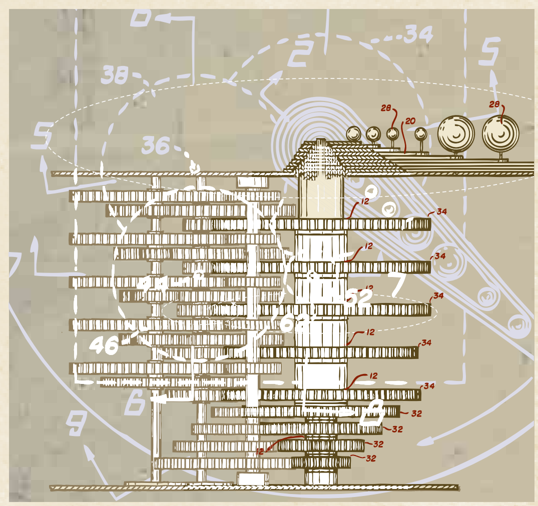
Visit www.fi.edu/history-science-and-technology for more information about the Automaton.

The Patent Models

The nineteenth century was a time of amazing growth in America. Within a relatively short span of time, the country was transformed from a rural society to an industrial giant. Patriotism, ambition, and optimism ran through the land like currents of electricity. The number of patents issued during this time was incredible, and the search for self-sufficiency and greater comfort made inventing a sort of national pastime.

On July 4, 1836, President Andrew Jackson signed a bill into law that established a new and improved patent system in the United States. All applicants needed to present three items prior to review for a patent: a written description, a schematic drawing, and a model of the invention.

When the 1836 bill was passed, Congress had more in mind for models than being just part of the requirement for a patent application. Models were also a way to educate the public, stimulate creativity and enterprise, and inspire a sense of America's destiny. The placement of Patent Models in "Amazing Machine" is true to the spirit of this original intention.



By the late 1860s, the number of patent models was growing at the rate of more than 13,000 annually. Since the bill never specified what patent models should look like or include, the Patent Office had amassed quite a diverse collection. Some models were classics of the modelmaker's craft; some were simple and unsophisticated. Some models were abstract; others were perfect miniatures.

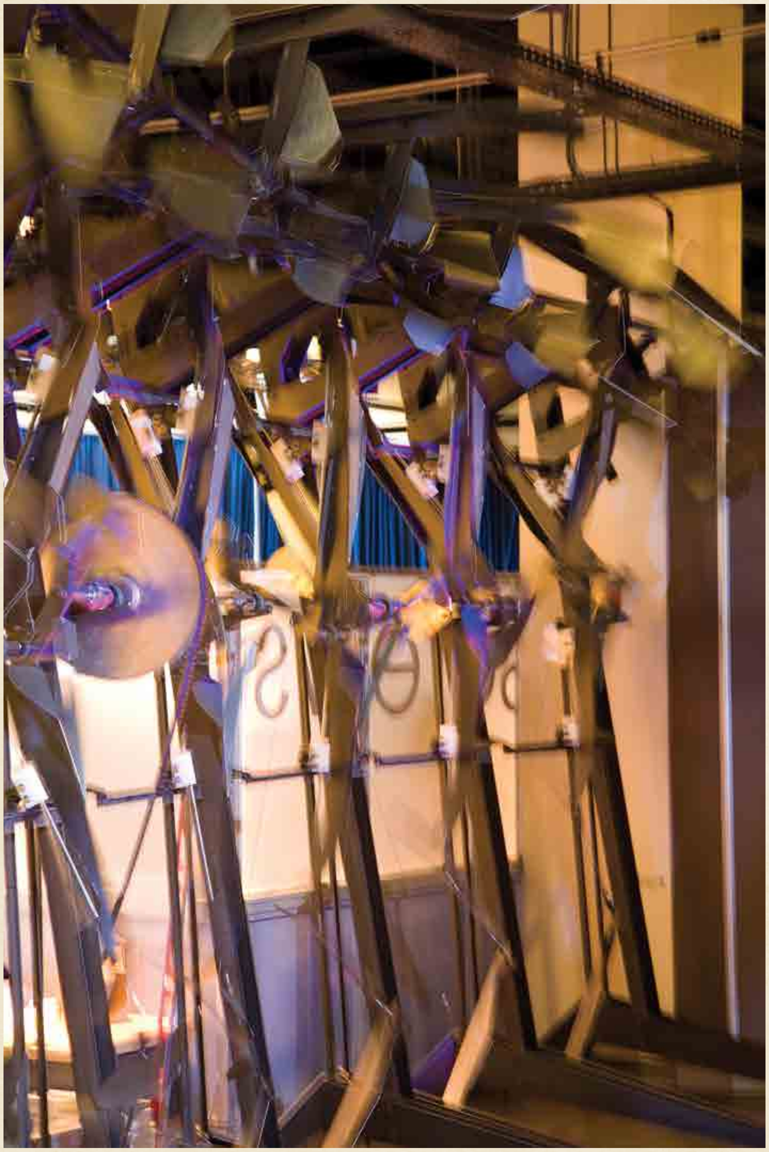
In 1908, Congress sought to dispose of the more than 150,000 models that still existed. Many had been on display in the Patent Office Museum, but fire and space issues caused the majority to be hidden away in storage. The Smithsonian selected 1,061 associated with famous inventors, and an effort to auction off the remaining models resulted in the transfer of only 3,000 others.

The rest, packed in oak crates, went back to storage until 1925, when Congress devised a plan to give those historically important models to the Smithsonian or other institutions, and dispose of all others by any means possible. The Patent Models on display in "Amazing Machine" came to The Franklin Institute as part of this final effort to clear the Patent Office of its collections.

Visit www.fi.edu/history-science-and-technology to learn more about the Patent Models.

Within "Amazing Machine," you'll find three kinetic sculptures which truly reveal the awesome beauty and elegance of mechanical motion. The first and most prominent is located at the entrance to the exhibit. The second is in the far corner, surrounded by glass windows which position the mechanical device in the natural world. The third is easy to miss, unless you remember to look overhead and see the horizontal display which forms the ceiling of the space.

Ben Trautman is the mechanical artist responsible for these three pieces. Based in San Francisco, Trautman is a sculptor, an old-fashioned tinkerer, and a man deeply fascinated with the mechanics of how things work. His kinetic sculptures invite you to share his fascination and to see the elegance of mechanical motion.



Curricular Standards

An exploration of the "Amazing Machine" exhibit can help students achieve learning objectives as called for by the national standards.

Next Generation Science Standards

K: Forces and Interactions: Pushes and Pulls
K-2: Engineering Design
K-3: Forces and Interactions
4: Energy
3-5: Engineering Design
MS: Forces and Interactions
MS: Energy
MS: Engineering Design
HS: Forces and Interactions
HS: Energy
HS: Engineering Design

Benchmarks for Science Literacy

3. The Nature of Technology
3a. Technology & Science
3c. Issues in Technology

8. The Designed World
8c. Energy Sources & Use

National Science Education Standards

K-4 A: Science as Inquiry
K-4 B: Physical Science
K-4 E: Science & Technology
K-4 F: Science in Personal & Social Perspectives
K-4 G: History & Nature of Science
5-8 A: Science as Inquiry
5-8 B: Physical Science
5-8 E: Science & Technology
5-8 F: Science in Personal & Social Perspectives
5-8 G: History & Nature of Science
9-12 A: Science as Inquiry
9-12 B: Physical Science
9-12 E: Science & Technology
9-12 F: Science in Personal & Social Perspectives
9-12 G: History & Nature of Science

Common Core English Language Arts

K-5: Reading Informational Text
6-12: Literacy in Science & Technical Subjects

Common Core Mathematics

K-12: Measurement & Data

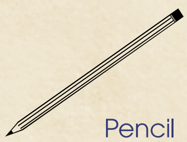
The Screw

TRY THIS!

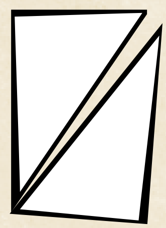
It's hard to imagine that a screw is really just a kind of inclined plane.

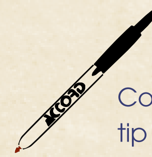
This activity will help you see what we mean!

THINGS YOU NEED:


Pencil


Scissors


Paper

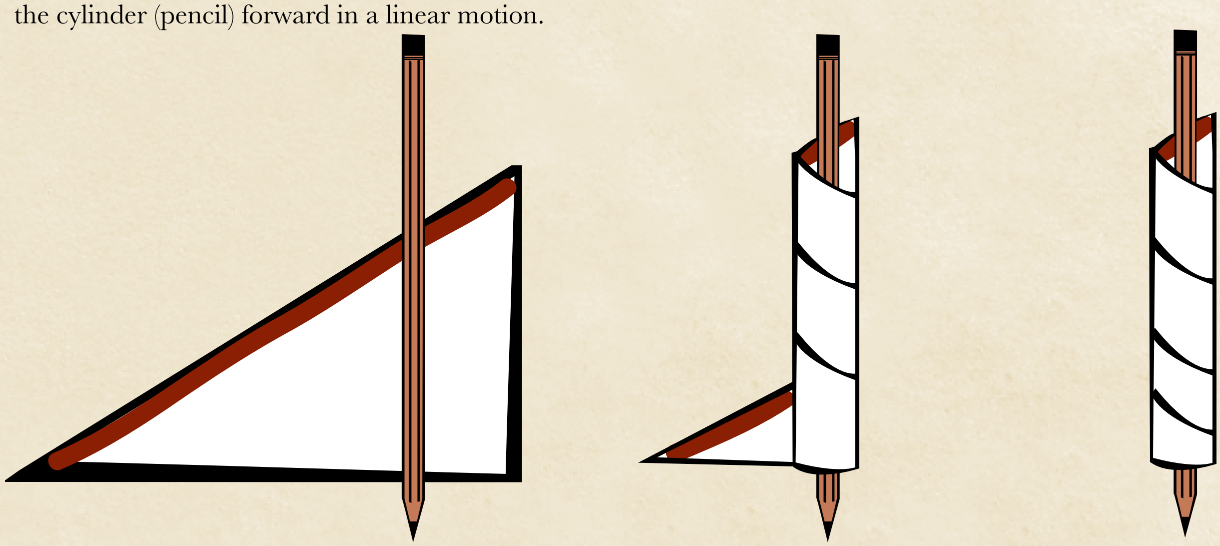

Colored felt tip marker

DIRECTIONS:

1. Cut a right triangle from the paper. The dimensions should be about 5 inches, by 9 inches, by 10.3 inches.
2. Use the felt tip marker to color the longest edge (10.3 inches) of the triangle.
3. Position the shortest side (5 inches) of the triangle along the side of the pencil and then evenly wrap the paper around the pencil by rolling the pencil.

NOTICE:

The colored edge of the inclined plane (triangle) forms the curve that causes the circular motion which moves the cylinder (pencil) forward in a linear motion.



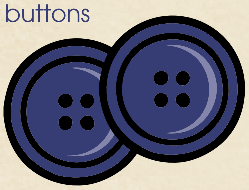
The Pulley

TRY THIS!

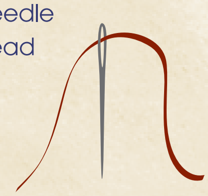
See how a simple pulley transfers energy from one end to the other.

THINGS YOU NEED:

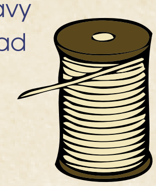
Two identical buttons



Sewing needle and thread

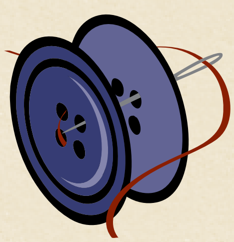


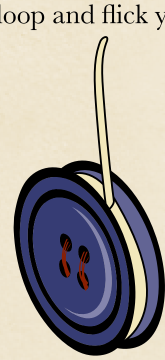
Spool of heavy cotton thread

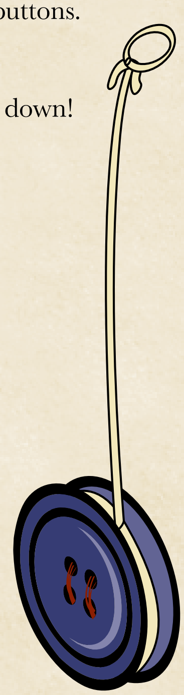


DIRECTIONS:

1. Thread the sewing needle with regular sewing thread.
2. Hold the buttons with their smooth sides together, sew them together and knot the thread.
3. Cut a piece of heavy cotton thread about 10-12 inches long.
4. Wind the heavy cotton thread between the connected buttons two or three times and tie a knot.
5. Pull the cotton thread tight and wind it all around the center of the buttons.
6. Tie a finger sized loop in the end of the thread.
7. Place your finger in the loop and flick your new button yo-yo up and down!







NOTICE:

A yo-yo is a simple pulley system that transfers the energy from your arm to the buttons and back again.

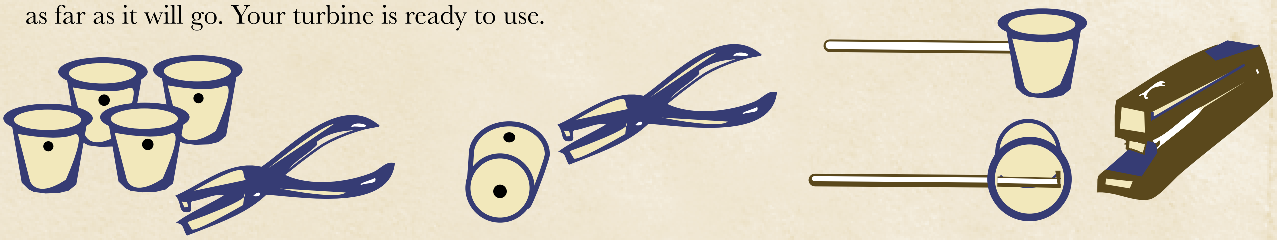
The Turbine

TRY THIS!

THINGS YOU NEED:

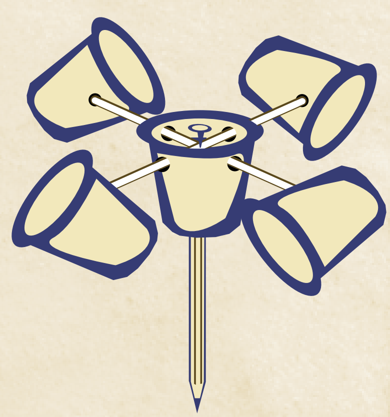
DIRECTIONS:

1. Take four of the paper cups. Using the paper punch, punch one hole in each, about a half inch below the rim.
2. Take the fifth cup. Punch four equally spaced holes about a quarter inch below the rim. Then punch a hole in the center of the bottom of the cup.
3. Take one of the four cups and push a soda straw through the hole. Fold the end of the straw, and staple it to the side of the cup across from the hole. Repeat this procedure for another one-hole cup and the second straw.
4. Now slide one cup and straw assembly through two opposite holes in the cup with four holes. Push another one-hole cup onto the end of the straw just pushed through the four-hole cup. Bend the straw and staple it to the one-hole cup, making certain that the cup faces in the opposite direction from the first cup. Repeat this procedure using the other cup and straw assembly and the remaining one-hole cup.
5. Align the four cups so that their open ends face in the same direction (clockwise or counterclockwise) around the center cup. Push the straight pin through the two straws where they intersect. Push the eraser end of the pencil through the bottom hole in the center cup. Push the pin into the end of the pencil eraser as far as it will go. Your turbine is ready to use.



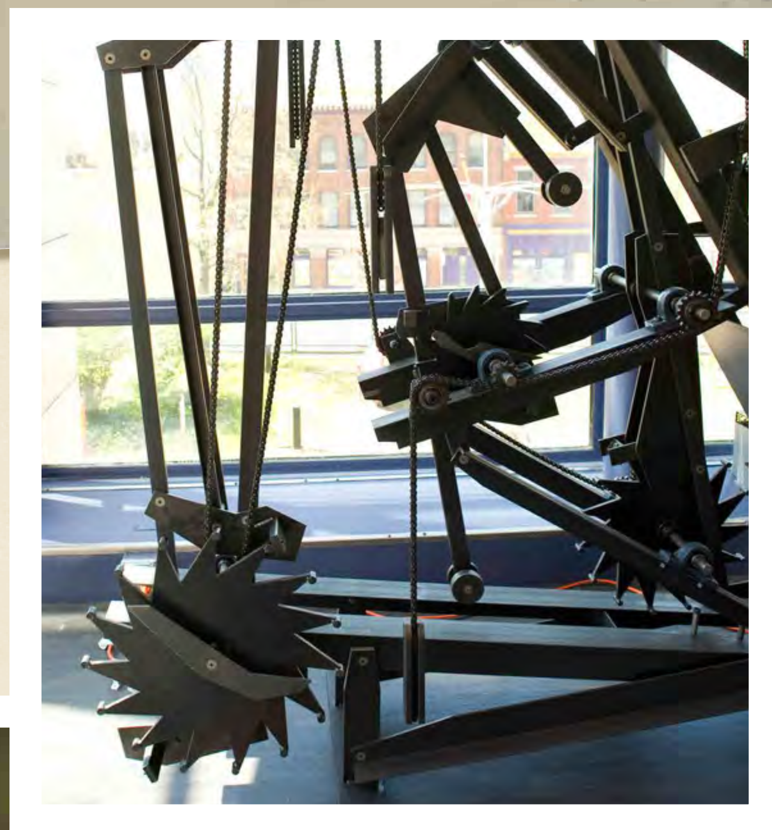
NOTICE:

This is a vertical-axis wind collector. In “Amazing Machine,” there is a Patent Model for a vertical-axis turbine that was designed for industrial manufacturing purposes. The device is on display in the entrance corridor.



Construction Challenges!

LEGO® and K'Nex® construction kits are filled with cams, gears, pulleys, and linkages. Challenge your students to design and construct machines—either for practical or artistic purposes. Try designing windmills or roller coasters. Or, let Ben Trautman's designs inspire students to assemble their own kinetic sculptures.



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