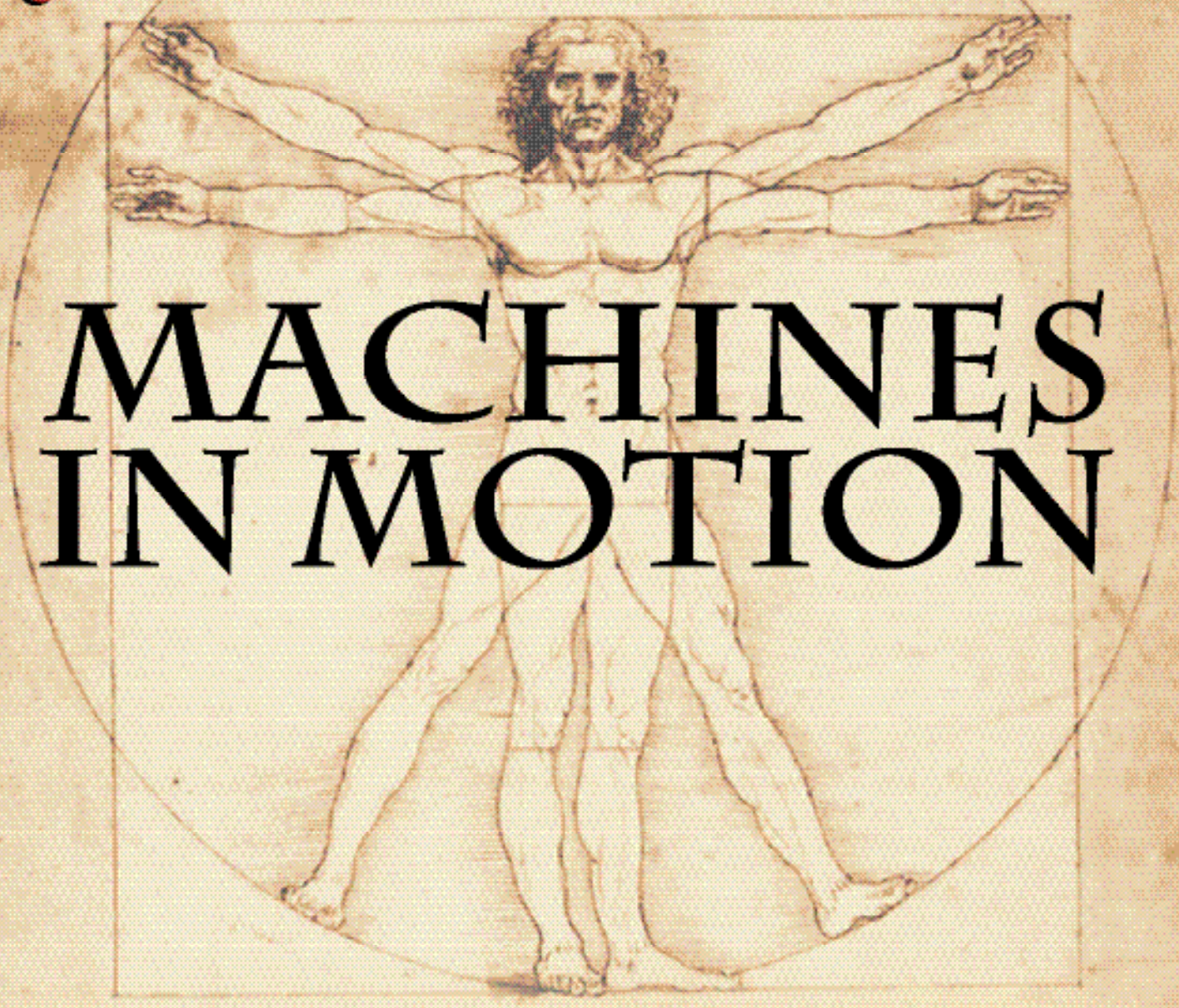
Leonardo da Vinci



MACHINES IN MOTION

Educators Guide

With Hands-On Activities for Upper Elementary and Middle School

I have been impressed with the urgency of doing. Knowing is not enough; we must apply. Being willing is not enough; we must do.

– Leonardo da Vinci

Dear Educator,

With this guide to The Genius of Leonardo we hope to support you and your students in accomplishing the "urgency of doing" in your classroom. These ten activities allow students to explore, discover and experiment with Leonardo's ideas with their own two hands. They will also learn to look for elements of his inventions in our lives today.

Here is an overview of what you can expect in the pages that follow:

All activities are open-ended and begin with a "Challenge". Students make and use a simple machine or an invention related to Leonardo's design and experiment with the machines they create. They develop and test their own designs.

The activities gradually increase in difficulty. Activities 1 through 5 are generally at the upper elementary level and 6 through 10 for middle school but you can pick and choose and adapt to best meet your students' needs. Activities can be used before or after your visit to the exhibit.

The wording of the activities is addressed directly to the student. Each page can be photocopied and distributed to your class. Supplies for the activities are inexpensive and easy to find.

Each activity page has one drawing of the machine in use today, one drawing to help your students understand the activity and a photo from the exhibit that relates to the activity.

Each activity is followed by a "What's Going On?" paragraph explaining the science principles behind the experimentation. At the end of this guide you will find resources for further exploration and ideas for extension activities.

On the next page you will find a summary by Art Historian Myrto A. Rogan to introduce you to the exhibit.

But "being willing is not enough; we must do." We hope you enjoy the "doing."

Sincerely,

Evergreen
Exhibitions

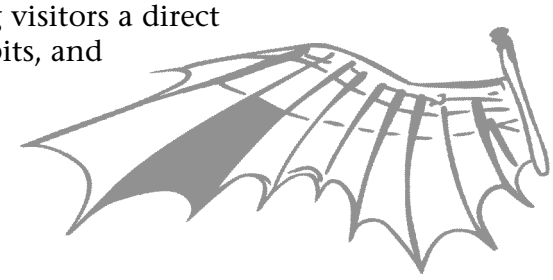
Leonardo da Vinci
MACHINES IN MOTION

Background on the Exhibit

What could a robot, armored vehicle, submarine, carjack, parachute and glider have in common with the enigmatic Mona Lisa and renowned image of the Homo Vitruvianus? Since they date back to the Italian Renaissance when science and the arts were flourishing, there could only be one man behind the invention of them all: Leonardo da Vinci (1452 – 1519), a genius the likes of which has never been seen again. He was an ecumenical thinker who explored the visible world with insight and precision, transforming his observations into images. In thousands of Leonardo's manuscripts compiled in the "Codices," each drawing is accompanied by explanatory notes, with image taking absolute precedence over text. Leonardo's notes are written from right to left, probably as a form of convenience for his left-handedness. The notes, which at first glance appear to be encrypted, can easily be read in a mirror.

Da Vinci did not compile his own manuscripts. The major task of gathering and grouping the works was initially undertaken by his sole heir; Francesco Melzi, after Leonardo's death; and then by the sculptor Pompeo Leoni, who bound them in two large volumes, the Codex Atlanticus, housed in Milan's Ambrosian Library, and the Windsor Collection, held in London. … Machines displayed in the exhibition *Leonardo da Vinci Machines in Motion* – are mainly derived from drawings in the Codex Atlanticus, comprising 12 volumes (1,119 pages) whose contents date back to 1478 – 1518; and in the Madrid Codices (1 and II), the first of which contains 192 pages of drawings from 1490 – 1496, and the second 157 pages from 1503 – 1505. *Leonardo da Vinci Machines in Motion* aspires to present the past master's art and multifaceted ingenuity; the researcher and scientist who devoted himself to the discovery and study of natural phenomena and human anatomy; the laws governing marine currents and waves; the flight of insects and birds; and the automation of manual tasks to save human labor.

Meandering through the exhibition, visitors will often be surprised to find the precursors of familiar equipment they use every day. On display are life-sized machines that visitors may touch and set in motion, traveling back in time to the days when Leonardo designed them at the end of the 15th century and early 16th century. … It departs from the austere model of artwork enclosed in a showcase, instead allowing visitors a direct relationship with the exhibits, and with their creator.

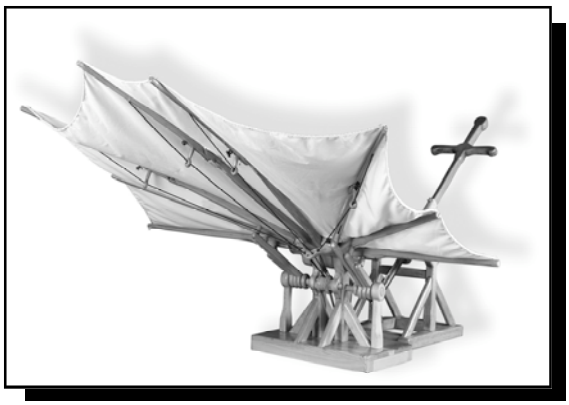


The forty machines on display, accompanied by the drawings from which they derive, are divided into four categories … each corresponding to the four elements of nature: Earth, Water, Air and Fire. The criterion for selection in each section is the element in which a machine operates, and/or from which it draws operational energy. In the Earth category, machines have been included that totally rely on human power, and that process or produce an item. Machines in the Water module generate power from that element or facilitate man's movement through water; the Air module contains da Vinci's impressive endeavors to conquer the skies with flying machines. Under Fire are examples of machine warfare that Leonardo was commissioned to design by the rulers who employed him.

Da Vinci's involvement in so many fields demonstrates once again his versatility, which was expounded by the man himself in a letter to the Duke of Milan, Ludovico Sforza, in 1492. In the letter, he states his capacities as architect, painter, sculptor, musician and engineer, and describes his prodigious works, laying emphasis on construction and the war machines he could build. The long list includes bridges, fortifications, catapults, rams, "roofed vehicles" (the precursors of modern armored vehicles), canons, engineering plans for river diversion and the construction of canals and buildings.

Machines displayed in *Leonardo da Vinci Machines in Motion* have not been arranged chronologically. Instead, they demonstrate the link between man and nature, and how man functions and labors with and within the elements of nature. All the machines have been constructed by Worldwide Museum Activities and are housed in the Museo delle grandi macchine funzionanti ed interattive tratte dai manoscritti di Leonardo da Vinci (Museum of the great functional and interactive machines originating in the manuscripts of Leonardo da Vinci) in Florence. … We hope that the exhibition will mark the beginning of a magical journey through secrets of the birth of modern science and engineering, in which one of the greatest geniuses in history will serve as your guide.

-- Myrto A. Rogan, Art Historian



1. Lever

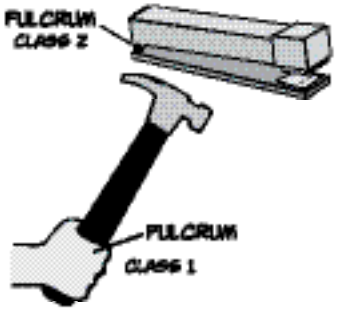
Leonardo's Wing Trial includes a lever that makes the wing move and a lever to operate the device. When you flap the wing, your arm works like a lever, too.

The Challenge: Invent a lever that can make a marshmallow fly.

You Will Need: large plastic spoon, ruler, marshmallow, pennies, pencil, hardback book, paper.

1. Look closely at the levers in Leonardo's invention. Every lever sits on a support, called a fulcrum, that helps you lift a load or weight -- in his case, a wing; in your case, the marshmallow.
2. Choose the best object for the main part of the lever, the part the marshmallow will rest on. If you have an idea of something that will work better that's not on the list, try that instead.
3. What will you use for your fulcrum? Experiment with different places to put the fulcrum to give you the most strength.
4. Record the distance the marshmallow travels with each of your levers. Why do you think some designs work better than others?
5. What force works best to launch the marshmallow?
6. When you have selected the best lever design, try launching other objects like the pennies. What adjustments do you need to make as the load gets heavier?

What's Going On? The three parts of a lever are the fulcrum, the load (the marshmallow) and the effort force (you pushing). It is easier to lift a heavy load if you move the fulcrum closer to the weight you want to lift. There are three classes of levers, depending on where the fulcrum, load and force are located.
In the illustration below, you will find: a **hammer** which is a class 1 lever, a **stapler** which is a class 2 lever, and a **shovel** which is a class 3 lever.



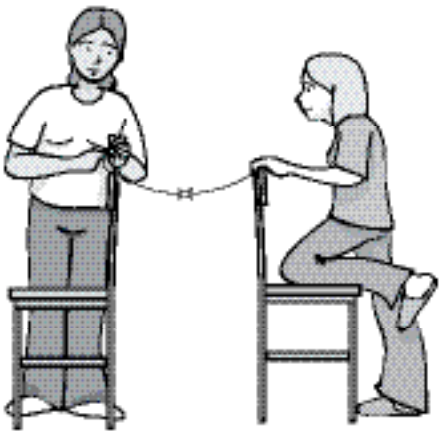
2. Pulley

Leonardo's crane design includes many of the same features you will find in cranes used today. Visit a construction site to see simple machines at work in the equipment all around you.

The Challenge: Pick up paper clips without touching them, using a pulley.

You Will Need: spool or toilet paper roll, 2 long pieces of string, 2 chairs, magnet, paper clips.

1. To help get your invention started, first put a piece of string through the center of the spool.
2. Attach one of the ends of the string to the back of one chair and the other to the other chair, so that the string is pulled tight. Your spool should be able to turn easily on the string.
3. Now for the pulley. How can you attach the second piece of string to the spool so that if you pull one end of the string the other end responds? Hint: Take a closer look at the photo of Leonardo's crane.
4. Attach the magnet to one end of the string. Can you pick up the paper clips?



What's Going On? A pulley is useful when you need to change the direction of the force you are using. If you pull down on one end of the string, the weight on the other end goes up. In a crane on a construction site, when you use the controls to pull down on the cable, it's a lot easier to pick up very heavy objects with the force of gravity on your side.

3. Wheel and Axle

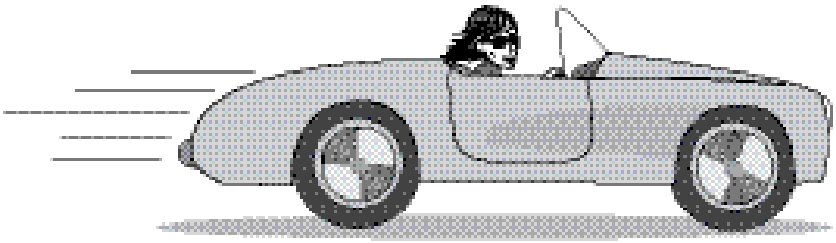
You can spot a wheel and axle wherever there is a cylinder attached to a larger wheel. You can find wheels and axles in any car. Fasten your seatbelt, and you're off!

The Challenge: Design a car that can carry weight.

You Will Need: a flat piece of Styrofoam or cardboard, scissors, 4 straight pins, pencil, something round to trace, pennies.

1. Trace your round object onto the Styrofoam, to make wheels.
2. Draw the shape you would like for the body of your car. Cut out the wheels and car body.
3. Stick one pin through the center of each wheel.
4. Attach the wheels to the sides of the car body, making sure they can turn freely.
5. Design experiments with your car. How can you make it speed up? What makes it slow down?
6. Can you design a system for the car to be propelled forward without you pushing it? Hint: One way to do this is with a balloon and a straw.
7. What happens if you make the wheels smaller or bigger or if you put extra weight, like the pennies, on the car?

What's Going On? When the wheels on a car turn, they reduce friction between the load (the car body) and the ground so that it can move along much more easily. The axle in your model car is the straight pin; the wheel rotates around the axle. Larger wheels require more energy to get moving, but they are better at reducing friction than smaller wheels so, once they are moving, your car should go faster. A wheel and axle in a car is a modification of a true simple machine such as a doorknob. In a doorknob, the axle is attached to the wheel so that they rotate at the same time. When you turn the knob, it moves the axle inside which helps to open the door.



4. Wedge

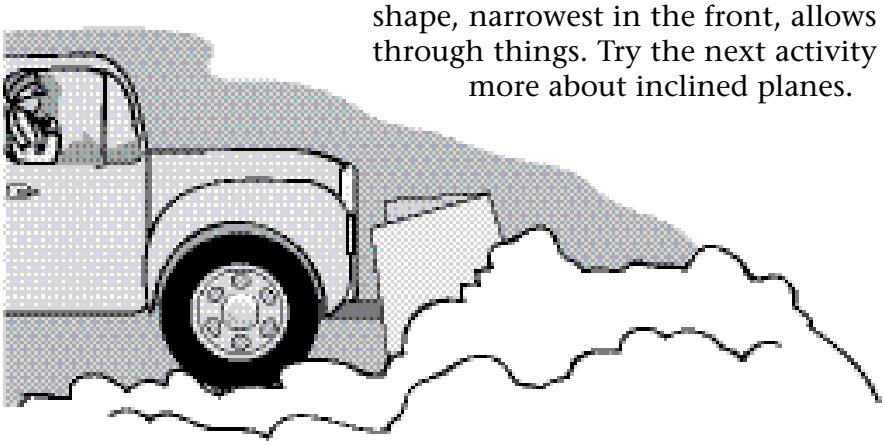
There are several ways that Leonardo's webbed glove helps you move through the water. One of these is its wedge shape, the way it is narrower at the end where your fingers are than at your wrist. Wedges are everywhere, if you know where to look.

The Challenge: Find the wedge that makes a zipper zip.

You Will Need: old item of clothing that uses a zipper, magnifying glass, pencil, paper

1. Make sure you are working with clothing that no one wants to wear anymore. Before you are done with this activity, you may have taken it all apart.
2. Study the zipper, very, very careful. Write down your observations. Use the magnifying glass to get a closer look.
3. What are the different parts of the zipper? Draw and label them. What is it made of?
4. Where is the wedge? Remember you are looking for a shape that is narrower in the front than the back and pushes through things, like the webbed glove pushes through the water and the snowplow through the snow.
5. What specifically does the zipper do? What other inventions might do it, but not as well? Can you think of a design that would do it better?

What's Going On? The zipper opens because of the wedge shape of the bottom of the slider, the part of the zipper that moves up and down. The front of a boat or a snowplow is also a wedge. A wedge is two inclined planes put together so that its shape, narrowest in the front, allows you to push through things. Try the next activity to find out more about inclined planes.



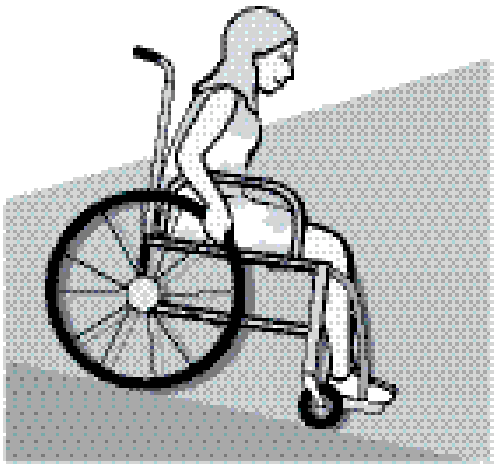
5. Inclined Plane

The Worm Screw model has two inclined planes, one that the screw rests on and one wrapped around the screw. Whenever you see a wheelchair ramp you are looking at an inclined plane.

The Challenge: Build a model of a wheelchair ramp that meets the Americans with Disabilities Act (ADA) standard of one foot of ramp for every one inch of rise.

You Will Need: books about 1/2 inch thick, ruler, yardstick or board at least 3 feet long, small toy car, pencil, paper, stopwatch or watch with secondhand.

1. Using the ruler, measure the thickness of your books. If your ramp is 3 feet long, how many inches high should your stack of books be?
2. Design an experiment with ramps of different heights by adding or subtracting books from the stack and leaning one end of the board on the top of the books. If your car is too wide to roll down, you can widen the ramp by taping a strip of poster board to the yardstick.
3. Use the stopwatch to record the length of time it takes for the car to go down ramps with different slopes. Be careful not to push the car down the ramp; just release it at the top. What do you notice?
4. People who use wheelchairs have to go up a ramp, too. How would you develop a test to address this?
5. Take a closer look at the wheelchair in the illustration. What simple machines do you see?



What's Going On? An inclined plane is a surface at an angle less than 90 degrees, propped against a flat surface. It allows you to use a smaller force over a longer distance to make it easier to raise a load or weight, in this case, a person in a wheelchair. If wheelchair ramps are not long enough for the height to be climbed, it is too hard for people to wheel themselves up. In your model ramp, you could see that if the stack of books was too high or the ramp was too short, the car flew down the ramp, out of control. This creates another big problem for people using wheelchairs if the ramp isn't designed correctly.

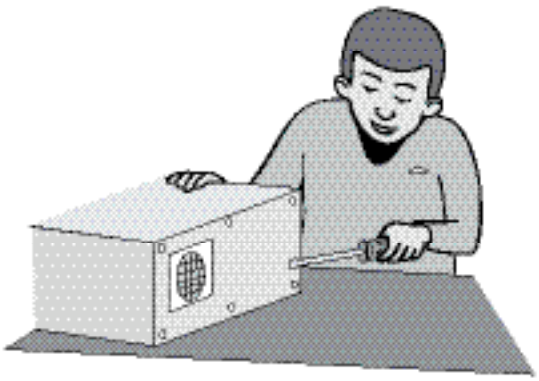
6. Screw

Screws come in handy whether you're lifting gigantic pillars like Leonardo or assembling your home computer. What makes them work so well?

The Challenge: Unwrap a screw and figure out how it's different from a nail.

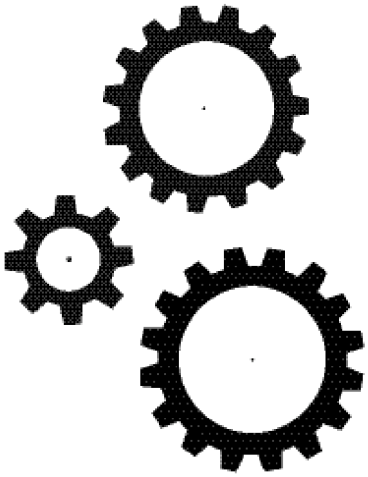
You Will Need: different sizes of screws and nails, pencil, paper, bar of soap, empty soda can, foil, masking tape, screwdriver.

1. Study the screws and nails carefully. Sketch a close-up version of the design of each.
2. Experiment with putting different sizes of screws and nails into the bar of soap. Remove the screws & nails and put them back in again. What do you notice? Is one easier to work with than the other?
3. Now put a screw into the soap using the screw driver. How is it easier than doing it with your hand? Study the shape of the screwdriver. What other simple machines are you working with?
4. Using the soda can as the center and the foil for the outside ridged area, mold and tape the foil to the can to make a model of a screw that matches the real one as closely as possible. What are the important design elements of the screw that make it work?



What's Going On? A screw is a cylinder with an inclined plane wrapped around it. The ridge around a screw circles up at an angle, making it easier to put it into the bar of soap (and harder to remove) than a nail. A screwdriver includes a wheel and axle (the handle is the wheel, the body the axle) and a wedge (the tip at the end).

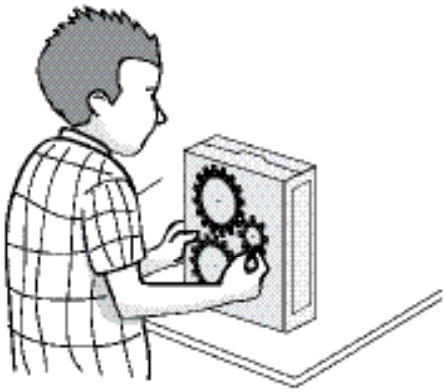
7. Gears



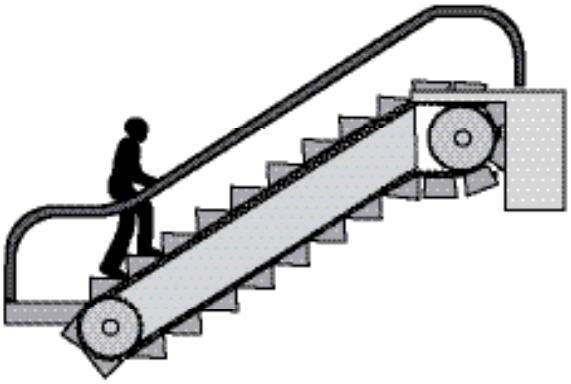
Gears are used to change direction, control different things at once, and to slow or speed things up. How do gears of different sizes work together?

The Challenge: Figure out how the circumference of connected gears relates to how many times each gear turns.

You Will Need: Styrofoam or cardboard, scissors, gear patterns included with this activity, paper, pencil, straight pins, empty cereal boxes, masking tape.



1. Trace the gear patterns on this page onto the Styrofoam. Cut out a variety of different sizes of gears. You can also make other sizes that aren't shown. Be careful that the teeth of all the gears are the same size and distance apart, no matter what size the gears are.
2. Measure and record the circumference of each gear. Circumference = Pi x Diameter. Pi = 3.14.
3. Stick a straight pin in the center of each gear. Turn the gear a few times to make sure it goes around smoothly. Does it remind you of a wheel and axle? That's because it is. It's a wheel and axle with teeth.
4. Stick the pins into the empty cereal boxes, arranging the gears so that their teeth interlock. If you move one gear the others should move. You will probably want to tape several cereal boxes together so that you can use more gears.
5. Experiment with each different gear, turning it to make the other gears move. What does the size of a gear have to do with the way it turns? When one gear turns one way, which way does the next one turn?
6. Rearrange the gears and continue to experiment. If a small gear is connected to a larger one, does it turn more often or less often? What data do you need to collect to prove your theory?



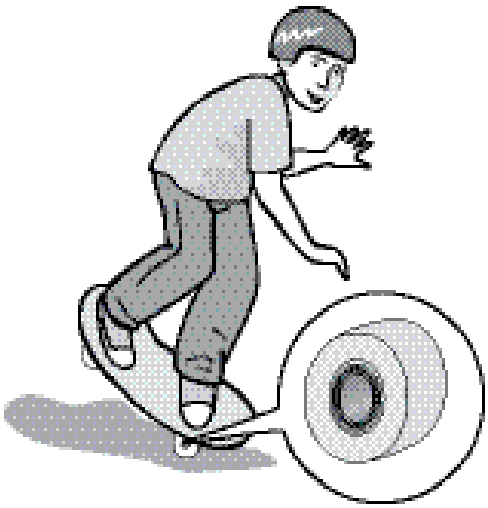
What's Going On? If two gears of different sizes are connected, the smaller gear will turn faster. Gear ratio means that if the circumference of one gear is three times as big as the other gear, the smaller gear will turn three times for every time the large gear turns – a gear ratio of 3:1. If two gears are the same size, they turn at the same speed. Gears that are next to each other turn in opposite directions.

8. Ball Bearing

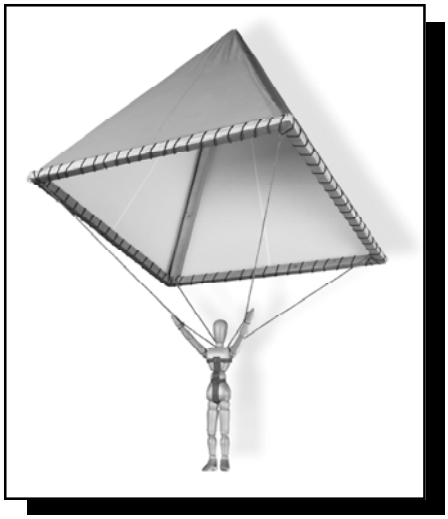
The Challenge: Make a heavy object easier to move by reducing friction.

You Will Need: large lid with a rim from a jar or paint can, bag of marbles, an object that is too heavy for you to easily slide across the table, paper, pencil, two different-sized, empty cans that fit inside each other (the circumference of one should be about 2" bigger than the other), other items to add to your invention.

1. Try to slide your heavy object across the table or floor. Notice how big the surface of the object is that touches the table as it moves.
2. Using the lid and the marbles, design a system to help the object move more easily. You don't have to limit yourself to those two items; you can add anything you like to the design.
3. Try sliding your heavy object again; make alterations to improve your design. Does your invention change the way the surface of the object touches the table?
4. Draw a plan for your invention like Leonardo did. Write a paragraph explaining its purpose. Be very concise. Imagine that someone is trying to build it many years from now.
5. Expand upon the elements of your invention using the two sizes of cans. What design would you use to help the two cans turn smoothly and quickly, one inside the other?



What's Going On? The marbles in this activity function as ball bearings. A ball bearing is a sphere in between two wheels of different sizes. When the outer wheel turns, it makes contact with the ball bearings, which are in contact with the inner wheel, which then also turns. The ball bearings reduce friction and make the wheel turn more smoothly because there is only a small contact point on the sphere with the inside and outside wheel. Ball bearings help a skateboard wheel to turn very fast while moving a heavy object – you! When you tried to move a heavy object without the ball bearings, more of its surface was touching the table, so the friction slowed it down.



9. Parachute

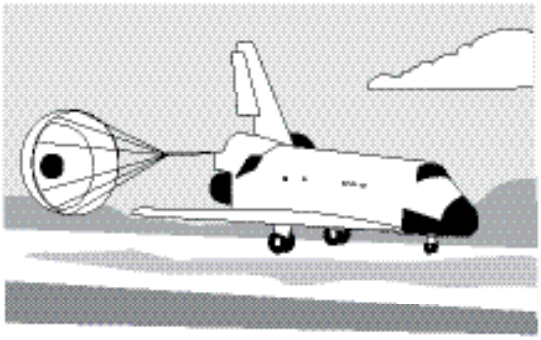
Leonardo's parachute is a very old invention with very modern applications. Why do you suppose it is still in use, even for slowing down the Space Shuttle?

The Challenge: Discover how the size of a parachute affects the time it takes to fall.

You Will Need: plastic garbage bag, scissors, ruler, paper, sharp pencil, 4 pieces of string per parachute, 1 small paper cup per parachute, stopwatch or watch with secondhand, a friend to help you, pennies.

1. Cut different sizes of squares from the plastic garbage bag. Each square will be used to create its own parachute.
2. Measure and record the area of each square. Area = Length x Width.
3. Poke holes in the 4 corners of each square. Tie one end of a piece of string to each hole.
4. Poke 4 holes in the edges of the paper cup, equal distances from each other. Tie the other end of each piece of string to one of the holes in the cup.
5. Have your friend get ready with the stopwatch and find a high spot to launch the parachutes.
6. What is your hypothesis? Which will land more quickly, the larger parachutes or the smaller ones? Drop each parachute from the same height and time how long it takes to land. Record your data.
7. Experiment with adding weight to your parachute by putting pennies in the cups. How would you need to adjust a parachute when its carrying a heavy load?
8. Look closely at Leonardo's parachute design. What advantages or disadvantages does it have over yours? Do you think it could land safely?

What's Going On? A parachute works because it creates drag from the air pulling on it, a force that slows down the falling object. The larger the parachute, the more drag it creates. Different sizes of parachutes are carefully designed to match the weight of the space shuttle or a person jumping from a plane. Parachutes are effective because they are lightweight and can be made in large sizes. They can catch a lot of air and create a lot of drag, but they are easy to carry. The wooden frame in Leonardo's design might cause problems when landing, but the basics of his invention are still in use today. A great idea doesn't have to be perfect. The first computers were so huge, **that a single one filled an entire room.**



10. Floats

Some things float and some sink, but can you make changes that cause a sinker to float?

The Challenge: Design a life jacket for an action figure.

You Will Need: plastic clear bucket or bowl, water, objects you can find around the house that are about the same size but different weights (like a small rubber ball and a rock), tape, marking pen, paper, pencil, ruler, cap from ballpoint pen, modeling clay, 2-liter bottle with cap, action figure, small balloons, twist ties.

1. Fill the bucket about 3/4 full with water. Put a piece of tape on the outside of the bucket and draw a mark on the tape to show the water line.
2. Put the different objects you collected into the water one at a time, observe the change in the water line. Measure and record the change for each object.
3. Now place the pen cap in the bucket, with the cap up so that air can stay inside the cap. What happens?
4. Remove the cap and attach a small piece of modeling clay to the end of the cap. What happens now? Add or subtract clay until the very top of the cap just floats above the water.
5. Fill the 2-liter bottle with water, carefully put the pen cap inside and close the top. What happens when you squeeze the bottle?
6. Using the action figure, the small balloons and the twist ties, design a life jacket that will keep the action figure's head above water. If you have ideas for other materials to make your life jacket, use them, too. Test the life jacket in the bucket. What do you observe?
7. Do you think you could stay afloat while wearing Leonardo's invention?

What's Going On? If the molecules in an object are more closely packed together, it has more density, more weight for its size. The denser objects displaced more water when you put them in the bucket. People float because they have less density than a large body of water, but to stay afloat you need help from the motion of your arms and legs. Your 2-liter bottle is a model called the *Cartesian Diver*. When you squeeze the bottle, you increase the pressure on the air inside the pen cap, decreasing its buoyancy and causing the cap to sink. A scuba diver wears a belt with weights on it to decrease buoyancy then sink and uses an inflatable device so that air can be added to increase buoyancy and float. Today's life jacket works by those same principles. Although enough water is displaced by the bags in Leonardo's invention to compensate for the person's weight, it would still be difficult to keep your balance. Walking on water is more successful in insects that, due to their body design, do not break the surface tension of the water when they move.

Extension Activities:

Here are some ideas to expand upon the activities in this guide.

Take it Apart - Bring common household items to school that are no longer in use and let your students study them and/or take them apart to see how they work and what simple machines might be inside.

Find da Vinci's Invention Today - Study all of Leonardo's inventions featured in the exhibit to find applications today. Discuss his influence on the world we live in.

Scavenger Hunt - At home, at school and in the exhibit, see how many simple machines you can find. The blinds in the classroom have a pulley, the tools in the garage include levers and wedges, and the kitchen includes many other examples.

Robotics - Study the differences and similarities between Leonardo's robot and robotics today. Discuss how advances in computer technology have changed the way we think about inventions and expanded upon what we are able to invent.

Da Vinci the Artist - Study the paintings of Leonardo da Vinci. Discuss how his knowledge of science may have impacted his art and how his art impacted the inventions.

Find out More about Leonardo da Vinci at the Following Websites:

http://www.bbc.co.uk/science/leonardo/
http://library.thinkquest.org/3044/
http://www.kausal.com/leonardo/
http://www.colorwithleo.com/

About Simple Machines and Inventions:

http://www.edheads.org/activities/simple-machines/
http://www.howstuffworks.com/

Credits

Evergreen Exhibitions has partnered with Worldwide Museum Activities of Florence, Italy to bring The Genius of Leonardo exhibition to the United States in 2008 for a limited three-year tour to nine cities. The exhibition is made up of 40 models and machines, most of which are interactive, from the genius of Leonardo, each one giving insight to his creativity and allowing visitors to interact and discover mechanical and engineering concepts as well as admire the beauty of his designs. There is a wealth of opportunities for multi-generational visitors to interact, wonder, and have fun in this exhibition – and to find inspiration. This Educator's Guide is designed to bring that inspiration into the classroom.

For further information about Evergreen Exhibitions, please visit **http://www.evergreenexhibitions.com/.**

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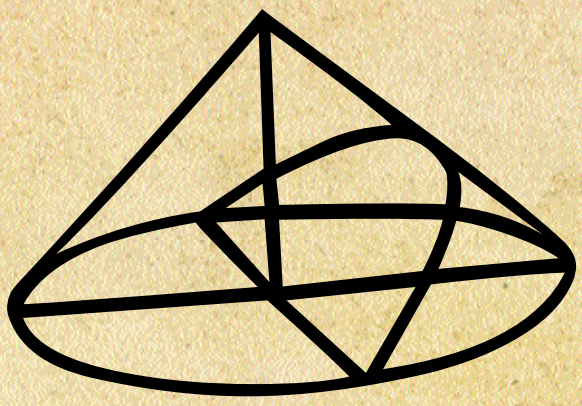

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For further information about *Leonardo da Vinci Machines in Motion*, or Evergreen Exhibitions, please visit
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