Mercer Museum
Pine & Ashland Street
Doylestown, PA 18901
215-345-0210
www.mercermuseum.org

School Programs At the Mercer Museum

The Simple Machines Program at the Mercer Museum

Dear Educator:

Thank you for choosing the Mercer Museum for you field trip destination. We hope it will be both educational and fun for your students. In our Simple Machines Program students will investigate examples of the six simple machines, explore how these machines make work easier, and have the opportunity for many hands-on experiences. Students are encouraged to make connections between the program and their tour of the museum, in which they will encounter many hand tools and simple machines used to meet the wants and needs of 18th- and early 19th-century Americans.

The following are suggested pre- and post-visit activities for students visiting the museum. The activity suggestions were created to make their field trip to the museum more meaningful and focused. There is also supplemental material on the subject of simples machine included in these materials to assist in your pre- and post-visit activities.

We would be interested in any feedback you can provide as to how we can make your visit, and these materials, more valuable and useful. Please feel free to contact me at any time.

Sincerely,

Melissa A. Jay

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Simple Machines in the Mercer Museum

Mercer Museum Artifacts and Exhibits Related to Simple Machines:

The history behind humanity's development and use of tools was at the core of Henry Mercer's original interests, and was central to his collecting and research. Now, in an age of electronic technology, the way things work is often hidden. The Mercer Museum's collection of everyday objects, however, offers numerous practical examples of the physical and mechanical principles that serve as the building blocks of science and technology. Here are some essential early American tools on view in the Mercer Museum that demonstrate simple machine concepts.

Levers-

Well Sweep: A counter-weighted first-class lever used to easily raise buckets of water from a well. *(Level 2, Central Court)*

Butter Scale: A device consisting of two platforms suspended on a rod that pivots freely on a fulcrum; used to weigh butter before sending to market. *(Level 2, Room 3)* Note: Many other types of balance scales are on view throughout the museum.

Shovel: A third-class lever in the form of a tool for moving dirt, grain or other materials *(several locations, including the Mining Exhibit, Level 4, Room 33)*

Scissors or Shears: Two first class levers working in tandem, though the blades of the scissors are also wedges. *(Level 3, Room 19 – Tinsmith's Shears; Level 3, Room 17 – Wallpaper Shears; Level 5, Room 52 – Sewing Scissors)*

Oar on Whaleboat: A first-class lever. The load is the resistance of moving the oar through the water; the fulcrum is the oarlock. *(Level 4, over hanging Central Court)*

Wagon Jack: A lever-operated device used to raise a wagon or buggy in order to repair, change or grease its wheels. *(Level 5, by Concord Stagecoach)*

Bag Cart or Hand Truck: A second-class lever composed of a wheeled plat form set at right angles to a ladder-like back with a set of handles; used to move bags of grain or other materials around the farm or mill. *(Level 5, under stairs to Columbus Gallery)*

Handle on Blacksmith's Bellows: A first-class lever. Pulling on the handle (force or effort) raises a chain or rope on the opposite end, com pressing the bellows and forcing air into the blacksmith's forge. *(Level 5, Room 46)*

Pounding or Plumping Mill: A first-class lever in which the force or effort is applied via waterpower. Water running slowly into the dished end of the lever fills it and adds weight, raising the pestle or pounder at the opposite end. When the dished end moves downward the water runs out and the pestle drops into the mortar crushing the grain. Process will repeat as long as water continues to run. *(Level 5, West Gallery)*

Handle on Grain Quern or Hand Mill: The handle, used to turn the top or runner stone on the mill, is a third class lever. The load is the stone to be turned and the fulcrum is the point above the worker into which one end of the handle is set. The miller's hands are between the two providing the effort or force. *(Level 5, West Gallery)*

Wheels-

Potter's Kick Wheel: Tool used by a potter to create vessels from clay. Potter pushes disk-shaped wheel at base of frame, which establishes momentum and transmits power (via an axle) to the turntable on which potter works. *(Level 2, Room 9)*

Candy Mixing Machine: A hand-operated mixer, turned via a crank. The crank turns a wheel with teeth – a gear – which transfers energy and motion to a second gear, which rotates the mixer. The large flywheel on top helps to sustain the motion. *(Level 2, Room 14)*.

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Buggies: Vehicles relying on spoked wheels for ease of movement *(Overhanging Central Court, Level 2)*

Square Plate Latch with Knob: This piece of 18th-century architectural hardware includes an oval doorknob attached to a shaft – a wheel and axle arrangement. Turning the knob results in raising the latch bar. *(Level 3, Room 29)*

Spinning Wheel: Tool used to twist animal or vegetable fibers (e.g. wool, cotton or flax) to make thread; wheel helps provide rapid and consistent motion, and transfers power to bobbin on which fiber is twisted. *(Level 4, Room 38)*

Grist Mill: Powered by water, and with the energy transmitted by a series of gears, the gristmill ground grain into flour. The top millstone, or "runner," rotated – as a wheel and axle – against the bottom stone, or "bedder," to grind the grain passing between the two stones. *(Level 5, North Gallery)*

Great Wheel Lathe: Cranked by an apprentice, the large wheel transferred power via a leather belt to a spinning lathe, on which a turner worked to make cylindrical shapes in wood. *(Level 5, West Gallery)*

Blacksmith's Blower: Turning the crank drives a belt, which turns a small wheel, which in turn drives a wheel with a set of baffles, forcing air through the opening in the blower. Used instead of the larger bellows to provide oxygen to the blacksmith's forge. *(Level 5, Room 46)*

Pulleys-

Pulley Block: This particular pulley was probably among those used to raise concrete and other building materials to the upper floors of the Mercer Museum during construction in 1913-16. "Lucy" the horse powered the pulley system or hoist. *(Level 3, Exhibit Case under Elephant Hotel sign)*

Inclined Plane-

Charcoal Burner's Ladder: A log that has been notched to create a simple ladder. Used by "colliers" to reach the top of a pile of wood that is being slowly burned to produce charcoal. Charcoal was used in large furnaces to extract iron from ore. *(Level 2, attached to column in Central Court)*

Horse Power: An inclined treadmill enabled the transfer of power (via a leather belt) from a horse walking on the treadmill to a machine like a thresher (used to separate grain from chaff). *(Outside Museum, East Carriage Shed)*

Wedges-

Felling Ax: Important lumbering, land clearing, and chopping tool used extensively during America's "Wooden Age." *(Level 3, Room)*

Pit Saw: Large two-person saw used to rip (saw lengthwise) boards out of a heavy timber. Pit saws were used with a trestle or a pit, in which one sawyer is pulling up on the saw at the top while the other pulls down from below. The sharpened teeth of the saw are the wedges. *(Level 3, over hanging Central Court)*

Plow: The share and the moldboard of the plow – used to break the soil and turn it over to prepare for planting – are both wedges. *(Level 3, Room 24 – Iron Moldboard Plow; Level 4, above stairs to Level 3 – Plowman Weathervane)*

Froe: Tool used, along with a wooden club or maul, for splitting out wood shingles to cover early American buildings. *(Level 4, Room 45a)*

Peg Maker: A circular wedge that simplified the process of making cylindrical wooden pegs or pins for the tines of rakes, or as trunnels ("tree nails") used to join pieces of wood together in furniture or house construction. *(Level 5, Room 56)*

Screws-

Cider Presses: Both the beam and screw-type presses relied on a large wooden screw to raise or lower weight onto the "cheese" (i.e., the layers of ground-up apples, set between layers of straw), resting on the bed of the press. *(Level 2, Central Court)*

Screw Augers: Boring tools used to make holes in wood; found in several exhibits around the Museum. *(e.g. Level 5, Room 56)*

Clamp: Screws tighten or loosen the jaws of the clamp, a tool to hold boards together for gluing, or to hold them down to a workbench. *(Level 5, Room 56)*

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Log Wheels: A tool to move logs out of the woods during lumbering operations. A log was chained to the heavy iron screw that ran down through the log wheel's axle. As the screw was cranked it lifted the front end of the log so that horses could pull both the wheels and the log, the latter with its rear end dragging. *(Level 6, Roof Gallery)*

Gears-

There are many examples of devices with gears in Museum exhibits, among them are:

- Grist Mill *(Level 5, North Gallery)*
- Apple Peelers *(Level 2, Room 5)*
- Fanning Mills: used to clean harvested grain *(Hanging above Central Court)*
- Candy Mixing Machine *(Level 2, Room 14)*

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School Programs At the Mercer Museum

The Simple Machines Program: Vocabulary

Simple Machines Vocabulary

Block and Tackle: A simple machine made up of more than one pulley.

Complex (or Compound) Machine: Two or more simple machines combined.

Effort: The force or energy you put into a machine to make it work.

Force: A push or a pull.

Friction: A force that exists between two surfaces in contact with each other, and that resists motion between these two surfaces.

Fulcrum: The point on which a lever pivots or turns.

Gravity: A force that causes objects on earth to fall.

Gear: A wheel with teeth. Teeth on one gear wheel mesh with the teeth of another gear, causing it to turn as well. Gears transmit power, reduce or increase force, and change the direction of a force.

Inclined Plane: A simple machine in the form of a ramp – a slanting surface that connects a lower level to a higher level.

Lever: A simple machine made up of a stiff rod or bar that pivots (or turns) on a support called a fulcrum.

Load: The object or material one is attempting to move or lift using a simple or complex machine.

Mechanical Advantage: The benefit gained by using machines.

Mechanism: A device that changes motion, transmits power or force, or controls motion, power or force. A mechanism may consist of one or more simple machines that work together to perform functions or tasks.

Pulley: A member of the lever family, a pulley is a simple machine that uses a grooved wheel and a rope to move a load.

Screw: A simple machine composed of an inclined plane wrapped around a pole or cylinder. Screws hold things together, press or crush things, or move things.

Simple Machines: Tools or devices that make work easier (or that lessen effort). Divided into the "Lever Family" and the "Inclined Plane Family" simple machines include the Lever, Wheel & Axle, Pulley, Inclined Plane, Wedge and Screw.

Wedge: A simple machine of the inclined plane family, used to push things apart. Wedges have at least one slanting side ending in a sharp edge.

Wheel and Axle: A simple machine of the lever family, composed of a spoked wheel or disk with a rod through the center.

Work: The effort needed to move an object multiplied by the distance an object is moved (E x D = W).

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Pre-Visit Materials: The Simple Machines Program

Suggested Activities-

- Review six types of simple machines with students. Use bibliography and web resources for background information.
- Ask students to bring to class an example of a simple machine from their house, e.g. a toy, a game, a simple (but safe) tool. Have students explain the way the machine works to their classmates.
- Classroom Exploration: Have students work in teams to identify as many simple machines as they can find in their classroom.
- Start a "Simple Machines Bulletin Board." Ask students to clip pictures from magazines of levers, screws, inclined planes, pulleys, wheels and wedges for posting.

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Post-Visit Materials: The Simple Machines Program

Activity 1-
Make a Wacky Machine (60 minutes+)

Materials and supplies required: recycled materials (tubes, cartons, spools, coat hangers, etc.), scissors, glue sticks, string, tape, rubber bands, craft sticks, straws, etc.

Procedure:

- Explain that you are going to break the group into 5-6 teams to create a wacky machine from simple and recycled materials. Each team will work in an area of the room. Show them where they can get the supplies they need.
- Give the teams a problem that they each have to build a machine to solve. The teams will all work on the same problem though their solutions are likely to differ. Their machines can be either full-scale or smaller models of full-scale machines. The problems you give them will vary. All will be relatively simple and a little silly, e.g.: *create a machine to squeeze toothpaste onto a toothbrush, to trap a mouse, to blow out birthday candles, to empty a trash can, to help them clean their room*, etc.
- Explain that their machine should incorporate at least one simple machine principle.
- They will have 45 minutes to work on the machines, followed by 15 minutes to show and describe their work.
- At the end of the time, have each group show and describe their machine.

Activity 2-
Pulleys Experiment (15-30 minutes)

Materials and supplies required: Two brooms or broomsticks, 25 feet of clothesline rope, pair of kid-sized gloves

Procedure:

- Assign two "strong" volunteers to hold the broomsticks. Find a "weak" one for the rope puller. Give the latter the gloves to protect his/her hands from rope burns.
- Instruct the broom holders to stand about 5' to 6' apart, extending their arms towards each other with the broomsticks parallel to the floor at waist level.
- Tie one end of the rope to the middle of one of the broomsticks.
- Wrap the rope around the middle of the other broomstick and give the free end of the rope to the puller. The rope puller should stand so that the rope will be pulled perpendicular to the length of the broomsticks.
- Tell the two broomstick holders to try has hard as they can to keep the broomsticks from coming together as the rope is pulled. Can the single rope puller draw the two broomsticks together? (Watch out for pinched fingers!)
- Repeat a few more times, wrapping the rope around the broomsticks one additional time for each trial. How much more difficult is it for the holders each time? How much easier is it for the puller?
- Ask what the students discovered. Essentially they created a pulley arrangement, with the broomsticks serving as the pulley wheels, with the rope looped around them. The load is the resistance supplied by the students holding the broomsticks. Note that the pulley has supplied "mechanical advantage." The MA of this pulley arrangement is equal to the number of rope lengths – or the number of times the rope is wrapped around the broomsticks. The trade-off is that the rope puller must pull the rope a greater distance for each "wrap."
- Mechanical advantage is a ratio of output force to input force. The better the MA the easier it is to do work.

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Post-Visit Materials: The Simple Machines Program

Activity 3-
Levers Experiment (15-30 minutes)

Materials and supplies required: Wide flat wooden ruler, hexagonal (not round) pencil, 20 - 1½" steel washers, masking tape, pen or marker (Note: if you wish your students to work on this in groups as a "lab" activity, multiply the supplies by the number of groups you wish to have).

Procedure:

Instruct students to tear two small pieces of masking tape, write "F" for "Force" on one and stick it on the 1-inch end of the ruler/lever. (If the ruler is both metric and "English," have students make sure they are working on the side marked in inches.

Label the second piece of tape "L" for "Load" and stick it on the 12-inch end of the ruler/lever.

Put the pencil/fulcrum under the lever at the 4-inch mark. Stack 4 washers (weights) on the Load end.

Gently use one finger to press down on the Force End of the lever/ruler to lift the load. Students should pay attention to how heavy the load feels.

Carefully stack weights one at a time on the Force End of the lever/ruler, just until the load weights at the other end are lifted up. Ask: How much force (in # of washers) was needed to lift the load?
Remove the force weights and slide the fulcrum under the 6-inch mark. The four load weights should still be on the Load End.

Gently use one finger to press down on the Force End of the lever to lift the load. Ask: Does the load feel heavier or lighter this time?

Carefully stack weights one at a time on the Force End of the lever just until the load weights at the other end are lifted up. Ask: How much force or effort was needed to lift the load?
Remove the force weights and slide the fulcrum under the 8-inch mark. The 4 load weights should still be on the Load End.

Gently use one finger to press down on the force end of the lever to lift the load. Ask: Does the load feel heavier or lighter this time?

Carefully stack weights one at a time on the Force End of the lever just until the load weights at the other end are lifted up. Ask: How much force was needed to lift the load?

Discuss and explain the outcome of the experiment/activity. Note that levers help do work by trading force or effort for distance. By changing the location of the fulcrum in this activity – that is, moving it farther away from where you are applying the force and closer to the load you are seeking to move, the work becomes easier. However, the height you are able to raise the load (the distance) becomes less.

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Activity 4-
Inclined Plane Experiment (15-30 minutes)

Materials and supplies required: 5 books, medium thick rubber bands, ruler, 2 thumb tacks, short string, small board or cardboard (about 1 yard long), block or some weighted container (Note: if you wish your students to work on this in groups as a "lab" activity, multiply the supplies by the number of groups you wish to have).

Procedure:

- Stack three of the books together.
- Put the board against the books to create an inclined plane.
- Using a thumb tack, attach a rubber band to the ruler at the zero end.
- Observe and record the distance of the hanging rubber band along the face of the ruler.
- Tie the string to the unattached end of the rubber band and attach the other end to the block or weight, using the other tack. (If several groups are doing this the strings should all be approximately the same length.)
- Lift the block up in the air and observe how far the rubber band stretches. Record distance.
- Now place the block at the bottom of the inclined plane. Ask students: What do you think will happen as you pull the block up the inclined plane? Do you think the rubber band will stretch more or less than when you lifted the block straight up?
- Pull the block up the inclined plane and observe how much the rubber band stretches. Record this measurement. Discuss the results only after students try to explain what they think happened.
- Repeat the experiment by using five books instead of three books. Have students predict and record the data. Discuss the results.
- Explain that an inclined plane offers a trade-off of force for distance. Pulling the weight up the board required less force than lifting the weight straight up (as measured by the stretch of the rubber band along the ruler), but the weight needed to travel a greater distance.

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Activity 5-
Wheel & Axle Windmill (15-30 minutes)

Materials and supplies required: A piece of colored construction paper 7" x 7" square, a long round colored pencil, an empty cardboard milk carton (half-gallon size), a 12"-long piece of light string, a Life Savers™ candy, pair of scissors, transparent tape, a pencil and ruler. (Note: if you wish your students to work on this in groups as a "lab" activity, multiply the supplies by the number of groups you wish to have). Have a sample of a finished windmill available.

Procedure:

- Using the pencil and ruler, draw a straight line from one corner of the construction paper to the opposite corner. Draw a second line that connects the other two corners. The lines should intersect at right angles at the center. Draw a small circle, ¼" in diameter, around the center point.
- Starting from each corner, use the scissors to cut along the lines to a point half way between the corners and the center point.
- Fold one free corner over so that it just touches the center circle. Tape the corner in place. Repeat this with the other three alternating corners. You should now have a pinwheel design.
- Poke a hole through the center circle and insert the colored pencil. It must fit snugly in the hole.
- Cut off the top of the milk carton (this could be done ahead of time as part of your preparation). Cut two slots, approx. 3/8" x 3/8," in opposite sides of the carton. Your "pinwheel" should fit loosely in and across these slots.
- Tie one end of the string to the candy. Tie the other end to the colored pencil and tie or tape it in place. Set the pencil in the milk carton slots.
- Hold the base of your windmill and blow on the "sails." The wind from your breath should cause the sails (the wheel) to turn, which also causes the pencil axle to revolve. The turning causes the string to wind up and lift the candy. You've created a wheel and axle that does work!

Activity 6-
Wedge Experiment (15 minutes)

Materials and supplies required: A 3" x 5" index card, ruler, tape, a piece of rigid lightweight cardboard approx. 8" x 10" (Note: if you wish your students to work on this in groups as a "lab" activity, multiply the supplies by the number of groups you wish to have).

Procedure:

- Fold the index card in half the short way.
- Fold ½" of each end of the card toward each other, overlap the ends and tape them. You should now have a small wedge.
- Slowly push the wedge under one end of the cardboard. You may need to hold the opposite end of the cardboard to keep it from skating away. Keep pushing until you have raised the cardboard as high as possible, without it tipping back over the wedge.
- Use a ruler to measure how far upward the cardboard moved. Compare this measurement with the distance you had to move the wedge under the cardboard. Students should find that they needed to move the wedge a greater distance to raise the cardboard a smaller distance. However the wedge gave them greater force and made their work easier.
- Ask students to consider how wedges of different sizes would affect the results of the experiment.

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Activity 7-
Screw Experiment (15-30 minutes)

Materials required: Long bolt and nut, wide flat washer that fits on bolt, plastic cylindrical bottle (with mouth larger than diameter of bolt), heavy brick or concrete block, paper clip, wrench to turn nut (Note: if you wish your students to work on this in groups as a "lab" activity, multiply the supplies by the number of groups you wish to have).

Procedure:

- Screw nut onto bolt. Add the wide washer and insert the thread end of the bolt into the mouth of the plastic bottle. Washer should rest flat against the mouth of the bottle.
- Place the bottle on its side so that its bottom rests against the brick or concrete block. Put a marker or pointer (the open paper clip) at the end of the block. This will help you to prove that you have moved the block.
- Put your foot on the end of the bolt so that it can't move. Use the wrench to turn the nut in the direction of the washer and bottle. The washer will push on the bottle top, causing the block to move.
- Ask students how hard/easy it is to move the block by turning the nut. Compare this with moving the block directly by hand without the machine.
- Note that students have again exchanged force for distance. The use of the screw made the work easier, though the force applied (hand moving the wrench) had to move a greater distance. Turning the nut put a big force on the block but moved it a very short distance, as proven by the paper clip marker.

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The Simple Machines Program: Bibliography

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