HISTORIC GERMANTOWN SCIENCE Sleuths

Section 2 : Historic RittenhouseTown

LESSON OBJECTIVE

*To understand how simple machines and the interplay between **kinetic** and **potential energy** explain the workings of a water-driven paper mill.*

Papermill Run (Creek) at Historic RittenhouseTown

Key Terms

Kinetic Energy

the kind of energy that an object has when it is moving. Kinetic energy can be transferred between objects and transformed into other kinds of energy.

Potential Energy

the energy held by an object because of its position relative to other objects, stresses within itself, its electric charge, or other factors.

Test your knowledge

Multiple choice

1. 1. This is NOT an example of a simple machine:

a. an ax
b. a crowbar
c. a microchip
d. a skateboard ramp

2. The Rittenhouse paper mill used:

a. mechanical energy
b. solar energy
c. gravitational energy
d. all of the above

3. Paper used to be made of:

a. wood pulp
b. linen rags
c. cardboard
d. sawdust

4. Waterwheels

a. Do not exist any more
b. convert the energy of running water into useful work
c. don't work when it rains
d. are always made of wood

Match the term with its definition

Undershot Wheel	○	○ energy created by the movement of an object
Hydraulic	○	○ energy inside an object waiting to be released
Potential Energy	○	○ wheel turned by water falling on it
Overshot Wheel	○	○ worked by running water
Kinetic Energy	○	○ wheel turned by water running beneath it

Short Answer

1. What simple machines make up a pair of scissors (name at least 2)?

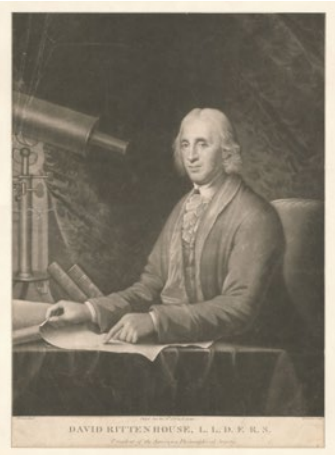
2. Give an example of kinetic energy.

Site History

The first paper mill at Historic RittenhouseTown was built by Wiliam Rittenhouse and his son Nicholas shortly after their arrival in the Colonies in 1690 on 20 acres of land on the north bank of Paper Mill Run (also called the Monoshone Creek). Through a partnership, they were producing high-quality paper by 1690. This was the first time paper was produced in the Colonies.

A flash flood destroyed the first mill in around 1701. Utilizing material salvaged from the mill, the Rittenhouse family built a second mill from stone rather than wood and used a different type of technology to drive the wheel. The first mill wheel (undershot) had been suspended over the Paper Mill Run and water flowing under it had caused the wheel to turn. The new mill (overshot) used water collected in a pool above the mill and diverted along a horizontal wooden race to the mill wheel, where the water fell nearly 20 feet onto the top of the water wheel, causing the wheel to turn. This type of construction gave the Rittenhouse family the ability to control the flow of water at the dam site and thus regulate the force of the water flowing over the wheel, minimizing potential damage in times of flood.

By 1703 the new mill was producing paper and, with some modification, continued in operation for 150 more years. The first permanent residential structure at Historic RittenhouseTown, the Homestead, was built in 1707 opposite the paper mill on the south side of Paper Mill Run. The Homestead and Bake House (c.1754) remain at the heart of the community into present times.



Above: A 1796 engraving of David Rittenhouse by Edward Savage from a painting by Charles Willson Peale

Key Terms

Overshot Wheel

a vertically mounted wheel with blades, buckets, or paddles that is rotated by water falling on top of it, with gravity causing the water to push on the blades

Undershot Wheel

a vertically mounted wheel with blades, buckets, or paddles that is rotated by the motion of water flowing underneath it, as in a river or a stream.

Above: A flowering flax plant

Philadelphia's first industrial village grew up around its first paper mill. To those who lived and worked at RittenhouseTown, the sights and sounds of a working mill were the stuff of everyday life. The rush of water, the hum of the water wheel, and the clatter of the hooves of horses echoed through the narrow valley cut by the rapidly moving Paper Mill Run.

Germantown, known as "the Workshop of the World," grew flax that was woven into linen. When the linen fabrics wore out, the rags were brought to RittenhouseTown to be made into paper. Paper produced at the Rittenhouse mill was sold to printers in Philadelphia and New York City.

Above Top: A wooden weaving shuttle used to weave spun flax into fabric. Above Bottom: An image of the second Rittenhouse mill from around 1880

As generations of Rittenhouse family members continued to live and work all along the Paper Mill Run and Wissahickon Creek, the village grew to meet their needs. Several more homes, numerous outbuildings, and barns, as well as a Baptist chapel for mill workers, a tenement building in which workers lived, a fire station, smithy, quarry, schoolhouse, and several more mills for grinding grain and producing textiles comprised the unique early industrial village that at its height comprised over 200 acres and at least 40 structures. Like so many industries that had utilized waterpower as their source of energy, and that now required coal and steam to run the heavy machinery, the RittenhouseTown mills ceased to operate.

Historic RittenhouseTown is listed on the National Register of Historic Places and was designated a National Historic Landmark District in 1992. The nonprofit organization, Historic RittenhouseTown, Inc., was founded in 1984 to preserve, restore, and historically interpret RittenhouseTown. Today the organization is committed to telling the story of the site from the industrial era to its current bucolic park setting in the Wissahickon Valley Park. Historic RittenhouseTown, Inc. offers educational programs, environmental stewardship, and cultural resources for the local community.

Did you know?

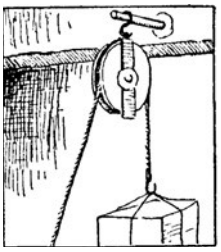
Philadelphia's Fairmount Park, created in the mid-19th century to provide parkland for City residents and to eliminate the sources of pollution, purchased the land and buildings that had once been RittenhouseTown. Today, only six of the original structures remain; the rest, including the paper mill itself, were demolished in the 1880s.

Historic Image of Rittenhousetown

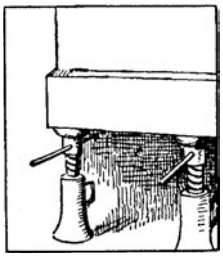
Types of Simple Machines:

Inclined plane: a surface that is placed at an angle to the ground that is used to raise or lower a load by rolling or sliding.

Lever: a rigid bar that pivots on a fixed point and transmits force, such as raising or moving a weight at one end by pushing down on the other.

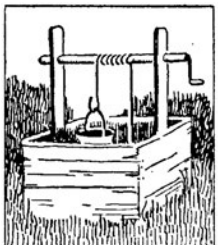


Pulley: a wheel with a grooved rim in which a pulled rope or chain can run to change the direction of the pull and thereby lift a load.



Screw: a cylindrical rod with one or more helical or spiral threads cut into it, often used to fasten pieces of wood or metal together.

Wedge: a piece of material, such as metal or wood, thick at one edge and tapered to a thin edge at the other, used for splitting, tightening, or blocking movement.



Wheel and axle: a cylindrical bar (axle) fastened to the center of a wheel

Did you know?

There are only 6 machines that make up all mechanical machines. The idea of a simple machine originated around the 3rd century BCE with the Greek philosopher Archimedes (c. 287–c. 212 BCE), who studied the so-called Archimedean simple machines: lever, pulley, and screw. You may have heard Archimedes' famous remark about levers: "Give me a place to stand on, and I will move the Earth." Heron of Alexandra (c. 10–75 AD) additionally lists the wheel and the wedge among five mechanisms that can "set a load in motion." During the Renaissance (15th- & 16th-century Europe) philosophers (now beginning to be called scientists) studied *mechanical powers*, as the simple machines were called, focusing on how far they could lift a load, in addition to the force they could apply, leading eventually to the new concept of mechanical work.

Did you know?

People have not always written on paper. Some drew on cave walls, some pressed wood into clay tablets, some painted words on silk or bamboo, and some wrote with ink on stretched, dried, and sanded animal skins (parchment). Today, wood-based paper is the most common type of paper found on earth. In 2018, the U.S. produced 72 million metric tons of paper. The earliest paper produced at Historic RittenhouseTown was made from flax, a plant grown in Germantown.

Above: A clay cuneiform tablet from around 173 B.C.E.

History of Papermaking

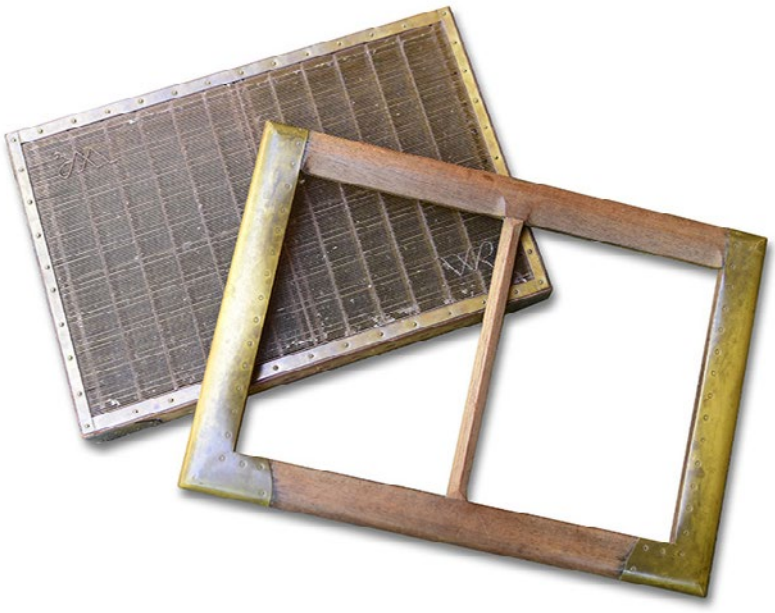
The first paper-like plant-based writing sheet was papyrus in ancient Egypt, but the first true papermaking process was documented in China during the Eastern Han Dynasty period (25–220 AD), where they used a process of pounding and stirring rags in water, after which the tangled fibers were collected on a mat and dried into sheets. During the 8th century, Chinese papermaking spread to the Islamic nations, replacing papyrus completely.

By the 11th century, papermaking made its way to Europe, where it replaced parchment and wood panels. By the 13th century in Spain, papermaking was streamlined with paper mills using waterwheels as an endless source of energy. Paper was historically made in the American colonies beginning the 17th century. The process started with the collection of linen rags. They were placed in water to ferment and then placed under the hollowed out stamping blocks of a beater powered by a water wheel. The rags were ceaselessly pounded for up to two days until the rags had been reduced to fibers suspended in water or paper pulp.

Right: Engraving of a water-driven paper mill from Denis Diderot's Encyclopedie 1751

Using a mold and deckle, the pulp was transformed into sheets of paper. The paper was then pressed using a simple machine that resembles a giant wooden screw and hung to dry. A final step in the process involved dipping the dried sheets in a solution or "sizing" that kept the ink from spreading into the fibers.

Later improvements to the papermaking process came in 19th-century Europe with the invention of paper made of wood pulp. It was through the observation of wasps chewing wood, mixed with their saliva, until it became pulp to make their nests that it was learned wood could be used as a source of paper pulp. Wood-based paper caused a major transformation of the 19th-century economy and society: with cheaper paper, schoolbooks, fiction, non-fiction, and newspapers became gradually available by 1900. Cheap wood-based paper also meant that keeping personal diaries or writing letters became possible.



Above: Photo of a Mold and Deckle marked with William Rittenhouse's intials "WR"

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Wood-based paper is the most common type of paper found today. In 2018, the U.S. produced 72 million metric tons of paper.

Key Terms

Mold and Deckle

a tool used in the process of making paper by hand. The mold is a rectangular wooden frame enclosing a screen of fine copper or brass wires that catch the pulp.The deckle is the top part of the tool: a wooden frame that fits neatly overtop the mold. The deckle helps to keep the pulp contained on the screen and creates the edges of the paper.

Supplemental Vocabulary

Hydraulic	moved by or operated by a fluid, usually water.
Battery	an array of hammers set in rows that are used to pound (batter) rags into pulp
Cam	A rotating or sliding piece with an irregular shape in a mechanical linkage used especially in transforming rotary motion (water wheel turning) into linear motion (hammering) or vice versa.
Couching	Large thick sheets of damp felt that the paper slurry is pressed between in order to draw out the water
Fiber	long strings of plant matter
Furnish	The water-suspended mixture of paper pulp and additives such as fillers, dyes, or sizing from which paper is made. After all the materials are added to the papermaking furnish, the pulp is turned into a slurry before being made into paper.
Screening	using a deckle to scoop up a thin layer of slurry to make a sheet of paper
Watermark	a symbol visible when paper is held up to the light. It is the best and only way to identify where paper was produced. Early paper makers twisted additional wires onto the surface of their molds into distinctive shapes, producing a 'watermark' or maker's mark. This was an effective way to distinguish their product from others.

Can't wait to see you at

HISTORIC RITTENHOUSETOWN!

HISTORIC Rittenhouse TOWN EST · 1690

www.Rittenhousetown.org

What have you learned?

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Data Analysis

1. Using rubber bands of various sizes, create a machine (slingshot) that uses the potential energy stored in the rubber bands' elasticity to convert it into kinetic energy. To test the potential energy for each rubber band, make sure you use the same size weight (ping pong ball, maybe) for each trial, and that you pull the rubber band the same distance each time. The angle of the slingshot should be the same each time as well, so you may want to create it with a stand. Measure the distance that each rubber band flings the ping pong ball to get an idea of the the stored potential energy of each.

2. Using the techniques you learned in the paper-making barn at RittenhouseTown, shred different types of materials and mix them with water in a blender, then create paper by pressing the slurry between two pieces of cotton sheets, using a sponge to sop up most of the water. Let your paper dry overnight before carefully peeling it off the sheets. Which materials create the strongest paper? Which materials make the smoothest paper?

Papermaking supplies

Writing Prompt

How many kinds of energy go into creating paper at the Rittenhouse Town paper mill? List the steps that go into creating paper, and discuss why the use of water power in a paper mill to make paper dramatically changed society. What could people do that they could not do before?

Links to Useful Sites

Khan academy - Simple Machines

Kinetic Energy vs. Potential Energy

Khan Academy - Work and the Work-Energy Principal

Wikihow.com - How to make a waterwheel

How to make a waterwheel

Science Project - Power from Water

DIY homemade slingshot

How to Make Your Own Paper

How paper is made (modern paper mill)

Make a DIY waterwheel (Video)

Site Lesson Extensions

Look at the data for the amount of work created by the various different waterwheels you tested at Historic RittenhouseTown. Now make a wheel using supplies you might have on hand, such as a pencil or metal rod for the axle, and craft sticks, cups, plastic spoons, or plastic egg half shells for the paddles or buckets. Using a steady current of water, see whether the overshot or the undershot wheel creates more work in the same amount of time. You can use the string method we used at the site, or you can try a different way of measuring the work, such as lifting a weight.

Illustrated diagram showing an undershot waterwheel (left), overshot waterwheel (middle), and breastshot waterwheel (right)

Hydraulic Engineer

A hydraulic engineer is a scientist who studies the flow and conveyance of fluids, usually water and sewage. One feature of hydraulic systems is the use of gravity as the main force causing the movement of the fluids. This area of engineering is closely related to the design of bridges, dams, canals, levees, and sanitary and environmental engineering.

Hydraulic engineers might study and direct the flow of city drinking water, the collection and treatment of sewage, or the control of city flood water and street runoff. They might also design and build hydroelectric dams, or design levees design levees (systems to keep the ocean from flooding a city during hurricanes). They are concerned with the transport of sediment by rivers and the interaction of the water with its banks. Hydraulic engineers develop designs for water-related features such as spillways, outlet works for dams, culverts for highways, canals and related structures for irrigation projects, and cooling-water facilities for power plants.

Did you know?

New research suggests that hydraulic mechanics may have been used in the construction of some Egyptian pyramids, including the Step Pyramid of Djoser, which is 4,500 years old.

A panoramic photo shows the hydraulic model design for the U.S. Army Corps of Engineers Sacramento District's Isabella Lake Dam Safety Modification Project. The 1:45 scale model allows engineers to test the design against extreme storms and improve it before construction begins. *U.S. Army Corps of Engineers via Flickr.*

Did you know?

Hydroelectric power represents the largest share of renewable energy in the world and will likely remain the world's main source of renewable power for the foreseeable future.

The Environmental Impact of Hydroelectric Dams

Huge hydroelectric dams have traditionally been seen as "clean" energy. Hydroelectric power represents the largest share of renewable energy in the world and will likely remain the world's main source of renewable power for the foreseeable future. Hydroelectric energy offers the clear benefit of helping reduce our dependence on fossil fuel, cutting down global greenhouse gas emissions, and helping us transition to 100% green and renewable energy.

Most hydroelectric power plants require the construction of a dam, which can result in the destruction of surrounding habitats. Dams may affect the migration and movement of fish, hinder their reproduction, and in some extreme cases, drive them to extinction. Also, as most hydroelectric projects are large in size, building them often leads to massive flooding of a river valley, wiping out homes, forests, fields, and animal and human habitats.

A wooden fish ladder allows salmon to make their way upriver around the Whitehorse dam and hydroelectric plant in The Yukon, Canada. *Photo by Jimmy Emerson, DVM via Flickr.* License

What's Happening Now? *(continued)*

So in recent years, people have been rethinking the effects of these dams on the environment. In order to save the salmon population along the Klamath River that runs along the California-Oregon state line, and to protect the Yurok tribe's way of life, the world's largest dam removal project is now underway: by the end of 2024, four aging hydroelectric dams along that river will have been demolished.

On a smaller scale, this is occurring elsewhere in the U.S. Plans to build new giant dams have been put on hold. A hydraulic engineer today would need to know not only how to channel water to get electricity out of it, but how to do so in ways that would cause the least amount of damage to the ecosystem surrounding it. *https://klamathrenewal.org/the-project/*

Klamath Basin Tribes and allies hold a rally at a meeting of the international hydropower industry in 2006. *Photo: Patrick McCully.* *License.*

Did you know?

When the Klamath River dam removal project is complete, One hundred thousand cubic yards of concrete, 1.3 million cubic yards of earth and 2,000 tons of steel will be hauled out of the river's path.

Acknowledgements

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Cover images include a solar microscope, bone slide with mosquito specimen, and meteorological tablets from the collection of the Wyck Association; Isaac Norris' Thirty Year Pocket Almanac from 1677 from the Stenton Collection on deposit at The Library Company of Philadelphia; and Hexamer General Survey of Wingohocking Hosiery Mills, Shoemaker Lane and Wingohocking Creek, Germantown, Philadelphia, Philadelphia County, Pennsylvania. vol.10 Plate 943, from the Free Library of Philadelphia.