Simple Machines at The Farmers' Museum
Interpreters' Guide

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Introduction

Many tools that 1840s farmers used can be classified as simple machines. A simple machine is a machine that operates without electricity and is used to make work easier for humans. A simple machine changes the power, speed, or direction of the movement of force. Citizens and farmers of upstate New York in the nineteenth century may not have viewed these machines through today's language of physics; however, they did know that it allowed them to perform tasks and jobs they could not perform without the help they received from these tools and objects. To understand more on the farmers' possible view and knowledge of physics review the section, The Nineteenth Century and Simple Machines. In using the Farmers' Museums collections to understand the life experience of farmers in 1845, it is imperative to appreciate simple machines and how they helped them.

This guide will give the museum educator an understanding of simple machines, the physics behind them, how a nineteenth-century farmer may have used them, and will provide curriculum that can be implemented in the museum setting to give students a full understanding of simple machines on the farm.

Simple Machines: The Basics

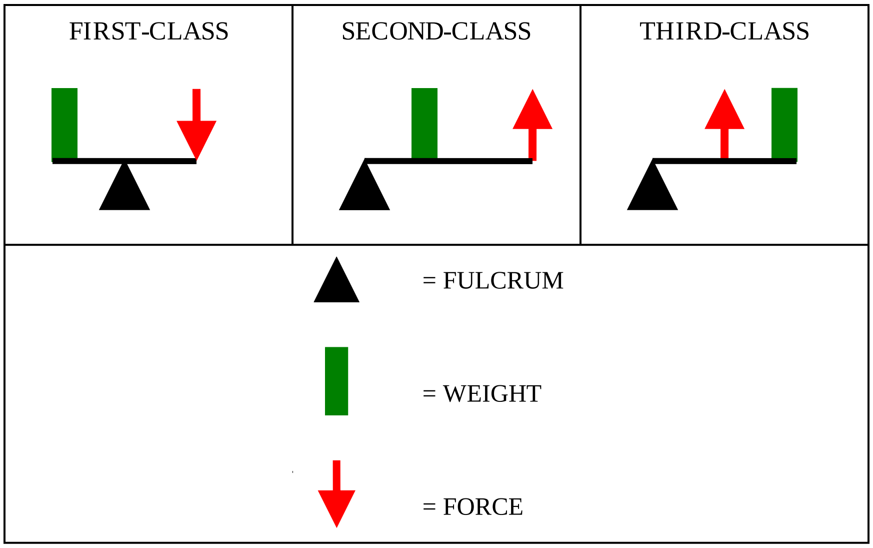
Simple machines can be classified into three basic types: the lever, the inclined plane, and the pulley. All other simple machines are made of combinations or modification of these three types. For example, common simple machines -- the wheel and axle, wedge, and the screw -- are modified rotating levers and two inclined planes, respectively.

At their basic level, simple machines are just tools that help us do work. What is work? In physical terms, Work is equal to Effort/Force multiplied by the distance a load was moved in the same direction as the Effort/Force. Technically, if something does not move, work has not occurred. **Most simple machines reduce the amount of effort force that is required to be exerted by increasing the distance the effort force has been applied.**

Every simple machine has a mechanical advantage. The mechanical advantage is how many times a machine multiplies the effort used. For example, using a machine with a mechanical advantage of two allows you to lift an object weighing 20 pounds with an effort force of only 10 pounds. As an interpreter it is helpful to understand mechanical advantage. The information to calculate the mechanical advantage of each simple machine is given with the individual descriptions of each type of simple machine (in the next few pages).

Levers

Levers have four parts (force, load, bar, and fulcrum) to lift loads or objects. There are three different classes or types of levels. The position of the parts in the relation to each other determines whether it is a first-class, second-class, or third-class lever).



Lever types

In a **first-class lever** the fulcrum is located between the load or weight of resistance and force. A teeter-tauter is a perfect example of a first-class lever.

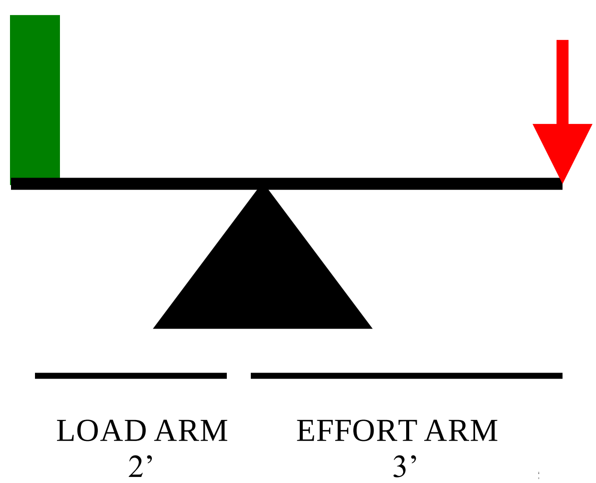
In a **second-class lever** the load or weight of resistance is located between the fulcrum and the force.

A wheelbarrow is the best example of a second-class lever.

In a **third-class lever** the force is located between the load or weight of the resistance and the fulcrum. A shovel – when used to scoop a load – is the best example of a third-class lever.

Mechanical Advantage of Levers

In levers, the mechanical advantage is determined by dividing the length of the effort *arm* by the length of the load *arm*. Therefore the first-class lever has a mechanical advantage of 1.5 more than if the work was done without the simple machine.



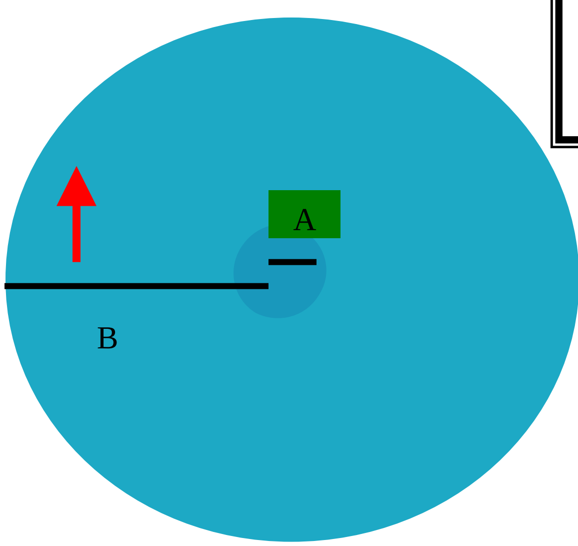
Wheel and Axle: a Rotating Lever

Wheel and Axle

Sometimes the wheel and axle is classified as a separate type of a simple machine; however, they are really a series of rotating levers (see activity: Around and round: How is a wheel and axle similar to a lever?). The point of rotation of the wheel and axle acts as the fulcrum, or the point of stability; the radius of the wheel, or the length from the center of the wheel to the edge of the wheel acts as the effort arm, and the radius of the axle acts as the load arm.

Mechanical Advantage of a Wheel and Axle

The mechanical advantage of the wheel and axle is calculated by dividing the radius of the wheel by the radius of the axle. Therefore the mechanical advantage of the wheel and axle pictured below would be 4.



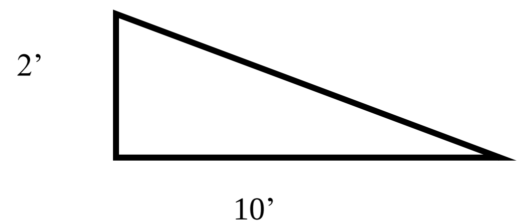
A = 2' (Radius of the Axle and the load)
B = 8' (Radius of Wheel and the effort)

Inclined Plane

In really simple terms an inclined plane is a hill or ramp. The ramp is a simple machine because it increases the distance (in the incline) that the load has to be carried or transported; therefore the amount of effort that must be exerted is decreased.

Mechanical Advantage of Inclined Plane

The mechanical advantage of an inclined plan is determined by dividing the length of the incline by the height of the incline. For example, the inclined plane pictured below has a mechanical advantage of 5.



Side View of an inclined plane

Wedges and Screws

Wedges and Screws, like the wheel and axle, are often put into their own category; however, they are all really modified inclined planes. Wedges – two inclined plans placed together and screws – are inclined planes wrapped around a cylinder and therefore, are variations of inclined planes.

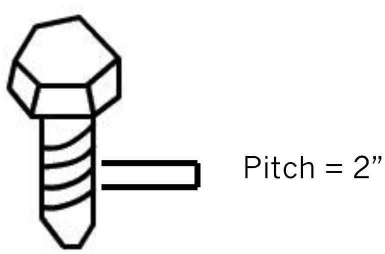
The wedge and the screw have something else in common – both exert a force that is applied in a right angle from the incline. Think about when a wedge is used to split wood -- the wedge is placed into small opening in the wood. When one pushes the wedge into the wood, the wedge applies force to the sides of the hole, or at a right angle to the wedge itself. Let’s explore a screw to see how it is similar.

The screw is an inclined plane wrapped around a cylinder (see activity, *Make a Screw*!). The important parts of a screw – or the parts that affect the mechanical advantage are: 1.the circumference of the cylinder, and 2. its pitch or how tight the inclined is planed bound around the cylinder. When one turns a screw or bolt into substrate, one must turn it several times to enter the substrate a very small distance. As with an incline plane when the distance decreases, the force increases, it is the same with screws.

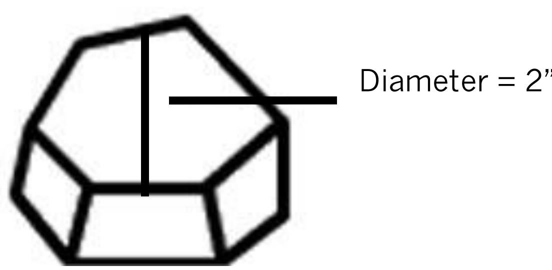
Mechanical Advantage of Screws

The mechanical advantage of screws is equal to the circumference of the cylinder divided by the pitch. The circumference is the distance around the outside of the cylinder. The pitch is the distance between two threads on the screw. In the example shown the circumference is equal to 6.28”. Note: circumference is calculated by multiplying pi (3.14) by the diameter (2”); therefore, the shown screw has a mechanical advantage of 3.14.

Side view of a screw

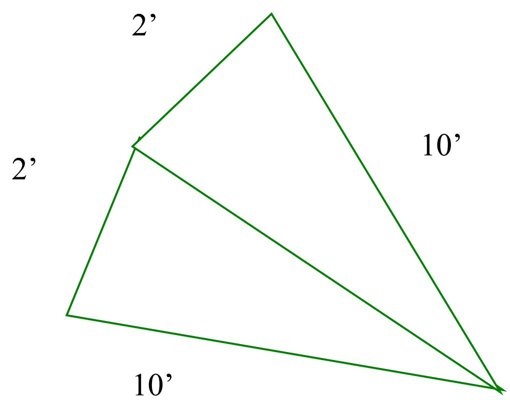


Top View of a screw



Mechanical Advantage of Wedges

The mechanical advantage of wedges is calculated by the same formula as inclined planes, with a slight difference. Because a wedge is two inclined planes, you must multiply the calculation by two. The mechanical advantage of the wedge shown is 10.



Side View of a Wedge

Pulleys

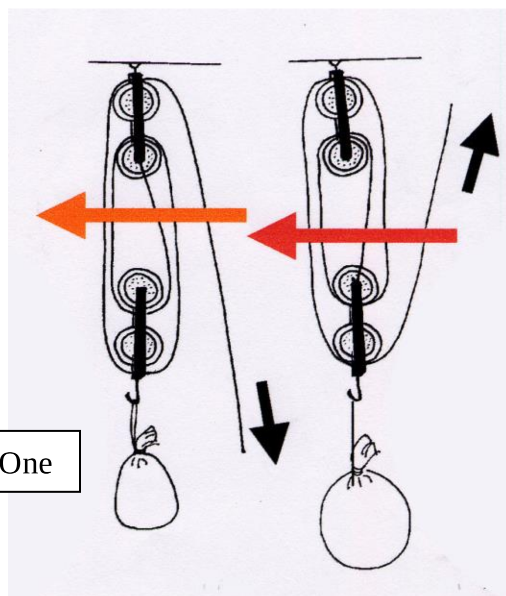
Pulleys are lifting machines that use a wheel with a groove and a rope. Pulleys can be stationary (see the activity *Flag Raiser*) or the wheels can move. When more than one wheel and groove system exists, it is called a compound pulley or a block and tackle.

Compound Pulleys

A compound pulley – or a block and tackle – is a series of two or more pulleys. The more pulleys that are on a block and tackle the great the distance the rope must travel; therefore, as we learned with the other simple machines, less effort force must be exerted by the individual using the tool.

Mechanical Advantage of Pulleys

The simplest way to calculate the mechanical advantage of pulleys is by counting the number of times the rope goes between the two wheels. However, you must be careful and only count the effort rope (the rope being pulled) if it moves in the SAME direction as the weight or load. For example, pulley one has a mechanical advantage of four; where as, pulley two has a mechanical advantage of five.

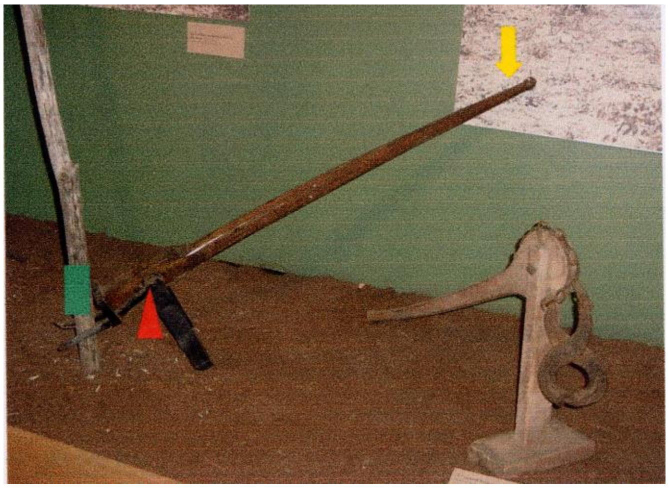


Pulley One

Pulley Two

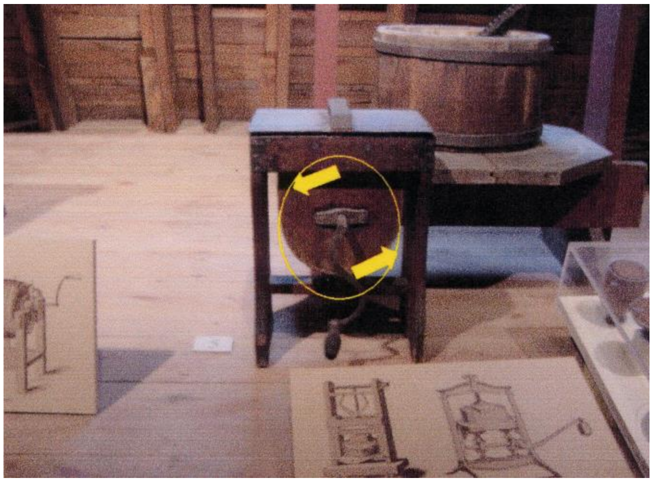
Simple Machines: Examples around the Farmers' Museum

This section gives examples of simple machines from around the farm. The photos are labeled by artifact and the type of simple machine that is represented by the artifact. Symbols are placed, where possible, to show the different parts (the load, the effort/force, and the fulcrum) of the simple machines.



Cant Hook = First Class Lever

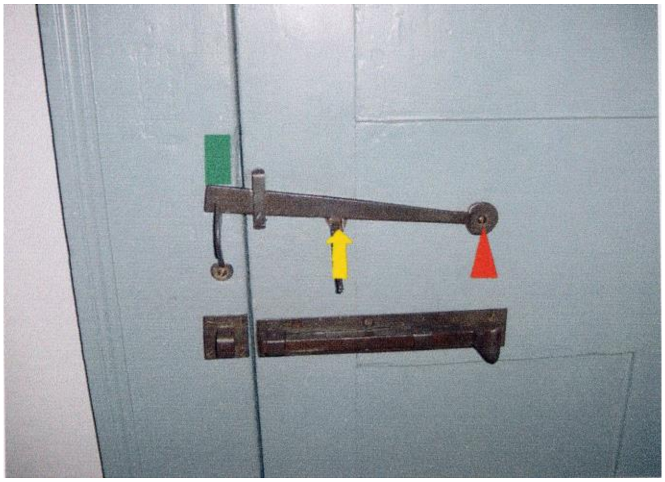
Plow = Inclined Plane or Wedge



Butter Churner = Wheel and Axle

Sledges, axes, and hammers = Third Class Levers

Tavern Stairs = Inclined Plane (note: the load would be you!)



Tavern Door Latch = Third Class Lever

Broom Press = Lever

Vice = Screws

Store Pulley, used to raise goods from the wagons or porch into storage

Test Yourself at the Lippitt Farm

The Lippitt Farm has many simple machines. Now that you have read through the types and explanations of simple machines, take some time to test yourself in the museum. The following list of tools is at the Lippitt Homestead and barnyard. They ALL represent types of simple machines or combinations of simple machines. See if you can decide which simple machine (s) they represent.

Fanning Machine

Corn Sheller

Wheelbarrow

Hop press

Shaving bench

Loom

Scissors

Answer key: Fanning Machine: levers, wheel and axle; **Corn Sheller**: wheel and axle; **Wheelbarrow:** second-class lever; **Hop press**: lever; **Shaving bench**: levers; **Loom**: levers, wheel and axle; **Scissors**: inclined planes and levers.

The Nineteenth Century and Simple Machines

During the early nineteenth century many people were fascinated with science and the knowledge that proliferated because of new discoveries and research. Gentlemen farmers were part of the obsession with science, or with the acquisition of a deeper understanding of material phenomenon. In fact James Fenimore Cooper had scientific books and manuscripts in his library collections (Jones, 1832). At this time physics or physical properties was called Natural Philosophy (Lauris, 1825). Natural Philosophy included the study of matter and its properties, the study of mechanical powers (such as simple machines), the study of astronomy, study of light and optics, and the studies of water, atmosphere, chemistry, and electricity. (Marret, 1820).

By 1845, the physics of simple machines had been discovered and tested; nevertheless, most farmers probably understood simple machines from their own experience and by communicating with other farmers. The excerpt from a textbook published in 1788 named *An Introduction to Natural Philosophy* shows the understanding of simple machines' mechanics during the late eighteenth century. The chapter labeled "Of the Mechanical Powers" states theories describing how bodies of matter related to each other:

"When two heavy bodies or weights are made by any contrivance to act against each other, so as mutually to prevent each other from being put into motion by gravity, they are said to be in equilibrio [sic]…Whatever therefore is proved concerning the weights of bodies will be true in like circumstances at other forces. The samples of those instruments, by means of which weights or forces are made to act in opposition to each other, are usually termed Mechanical Powers. Their names are the Lever, the Axis and

Wheel, the Pulley or Tackle, the inclined plane, the wedge and the screw (Nicholson, 1788)."

The textbook then describes the different simple instruments. The author describes the lever, for example, in the following way: "A lever is…a moveable and inflexible line, acted upon by three forces, the middle one of which is contrary in direction to the other two. One of these forces is usually produced by the reaction of a fixed body, called the fulcrum."

In the nineteenth century, technology grew out of personal experience with the properties of things and with the techniques for manipulating them, out of know-how handed down from the experts to apprentices over many generations. There was an understanding of the physical properties of the machines.

Below is a list of key dates in the history of physics in relation to the Farmers' Museum's interpretation year.

335 BC	Strato: Performed experiments of free falling bodies and levers
330	Aristotle: Physics and metaphysics experiments
240	Archimedes: Established the principle of levers and compound pulleys.
1225 AD	Jordanus Nemorarius: mechanics of lever and composition of motion.
1515	Leonardo de Vinci: experiments that led to progress in mechanics.
1609	Johannes Kepler: experimented with the notion of energy.
1615	S. De Caus: trials with forces and work.
1638	Galileo Galilei: experimented with motion and friction
1665	Isaac Newton: performed studies on the principles of mechanics, gravity, mass, and force.
1668	P. Varignon: carried out tests on the addition of forces
1687	Isaac Newton: published laws of motion and gravity.
1743	Jean d'Alemberf: performed tests on energy in Newtonian mechanics
1798	Benjamin Rumford: experimental relation between work done and heat generated.
1845	Farmers' Museum interpretation year

Appendix One: Glossary

Axle: a bar, rod, or cylinder attached to the center of a wheel or at the end of a rotating lever.

Effort Arm: the distance from the effort force to the fulcrum.

Force: a push or pull on an object that causes it to change direction, move, or stop.

Friction: the rubbing force of one object against another object. Friction causes moving objects to slow down, for example a free rolling ball.

Fulcrum: the resting or balance point where a lever pivots.

Gear: a wheel with groves, ridges, or teeth. One gear connects with and turns another gear.

Inclined Plane: a sloping surface used to move heavy things up or down.

Lever: a solid bar, rod, or cylinder that turns on a fulcrum. It is used to move loads. There are three types of levers:

First-class lever: Fulcrum is between the effort and the load
Second-class lever: Load is between fulcrum and force
Third-class lever: Effort force is between the load and the fulcrum

Load Arm: the distance from the load to the fulcrum

Newton: one newton is equal to 0.2248 pounds

Mechanical Advantage: how many times a machine multiplies the effort used.

Pitch: in a screw, the vertical distance between threads

Pulley: a wheel with a groove that a rope or wire fits into used to lift or move things

Ramp: an inclined plane

Screw: an inclined plane that winds in a spiral around a cylinder. It is used to move (as a in a car jack), fasten (as in construction), or add pressure (as in a cheese press).

Simple Machine: a machine that operates without electricity and is used to make work easier. A simple machine changes the power, speed, or direction of the movement of force.

Wedge: is two inclined planes. Usually used to separate or split objects.

Wheel and Axle: a wheel is a rotating lever. An axle is a bar or rod attached to the center or end of the rotating lever. Together, they can be used to move loads, change force, speed, or the direction of movement.

Appendix Two: Resources for Educators

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+http://sciencespot.net/Pages/classphyslsn.html