

Simple Machines

Compiled and edited from Wikipedia

Inclined Plane

An inclined plane is a plane surface set at an angle, other than a right angle, against a horizontal surface. The inclined plane permits one to overcome a large resistance by applying a relatively small force through a longer distance than the load is to be raised. In civil engineering the slope (ratio of rise/run) is often referred to as a grade or gradient.

Examples of inclined planes are ramps, sloping roads and hills, carpenter's and planes. The most canonical example of an inclined plane is a sloped surface; for example a roadway to bridge a height difference.

Another simple machines based on the inclined plane include the blades and wedges, in which two inclined planes placed back to back allow the two parts of the cut object to move apart using less force than would be needed to pull them apart in opposite directions.

Aircraft wings, helicopter rotors, propellers used in aircraft and boats, windmills, water wheels, turbine blades, and fans are also specialized examples of inclined planes.

The ramp or inclined plane was useful in building early stone edifices, roads and aqueducts. It was also used for military assault of fortified positions. It was invented by the ancient Egyptians as were the lever and the clock.

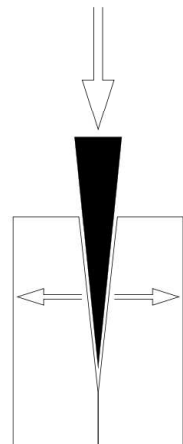
- Wedge

A wedge is a simple machine, technically a portable double inclined plane, used to separate two objects, or portions of objects, through the application of force, perpendicular to the inclined surfaces, developed by conversion of force applied to the wide end. The mechanical advantage of a wedge depends on the ratio of its length to its thickness. Where a short wedge with a wide angle does the job faster, it requires more force than a long wedge with a smaller angle.

The origin of the wedge is unknown, because it has been in use as early as the stone age.

- Screw

A screw is one of the six simple machines. A simple screw is a helical inclined plane. A screw can convert a rotational force (torque) to a linear force and vice versa. The ratio of threading determines the mechanical advantage of the machine.



Lever

A lever is a rigid object that is used with an appropriate fulcrum or pivot point to change the mechanical force that can be applied to another object. The principle of leverage can be derived using Newton's laws of motion, and modern statics. The lever only allows one to trade effort for distance or vice versa.

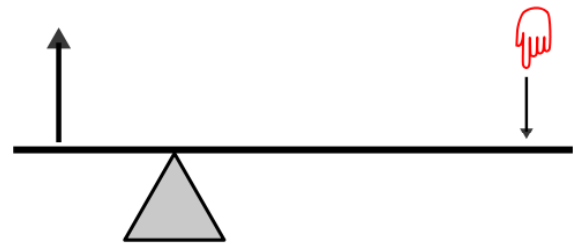
The earliest remaining writings regarding levers date from the 3rd century BCE and were provided by Archimedes. Give me the place to stand, and I shall move the earth is a remark of Archimedes who formally stated the correct mathematical principle of levers (quoted by Pappus of Alexandria).

In ancient Egypt, builders used the lever to move and uplift obelisks weighing more than 100 tons.

There are three classes of levers representing variations in the location of the fulcrum and the input and output forces.

- First-class levers

A first-class lever is a lever in which the fulcrum is located in between the input force and the output force. In operation, a force is applied (by pulling or pushing) to a section of the bar, which causes the lever to swing about the fulcrum, overcoming the resistance force on the opposite side. The fulcrum is the center of the lever on which the bar (as in a seesaw) lays upon. This supports the effort arm and the load.

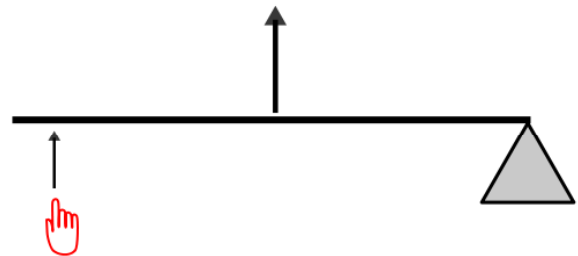


Examples:

- seesaw (also known as a teeter-totter), crowbar, claw hammer (removing nails), pliers (double lever), scissors (double lever), wheel and axle, load arm, and effort arm principle, oars, when used for rowing, steering, or sculling, can opener, bottle opener, bicycle hand brakes

- Second-class levers

In a second-class lever the input is located to the far side of the bar, the output is located in the middle of the bar, and the fulcrum is located on the side of the bar opposite to the input.

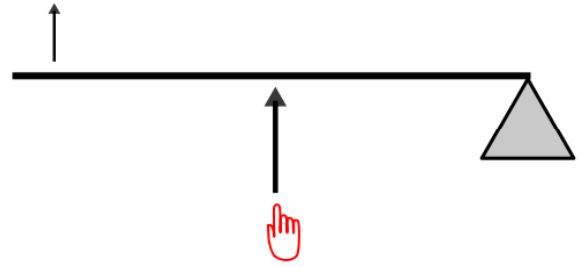


Examples:

- wheelbarrow, nutcracker, door, crowbar, stapler, diving board, wrench

- Third-class levers

It is to be noted that for this class of levers, the input effort is higher than the output load, which is different from the first-class and second-class levers. However, also notice that the input effort moves through a shorter distance than the output load. Thus it still has its uses in making certain tasks easier to do.



Examples:

- human arm, tweezers, slings, fishing rods, tools such as a hoe or scythe, baseball bat, shovel, broom, staple remover, golf club, hockey stick, human mandible

- Wheel and Axle

The wheel and axle is a simple machine. It consists of a large wheel that turns an axle around which a cord is wound. A heavy weight attached to the cord can be lifted more easily because of mechanical advantage. The wheel and axle can be considered to be a lever in which the radius of the wheel is the effort arm and the radius of the axle represents the resistance arm. It also is a single forced machine. By changing the short distance of lifting, the force is less because the work always stays the same.

Screwdrivers, doorknobs, windmills, gears, and Chain Falls are all examples of the wheel and axle.

Pulley

A pulley is a wheel with a groove along its edge, also called a sheave, for holding a rope or cable. Pulleys are usually used in sets designed to reduce the amount of force needed to lift a load. However, the same amount of work is necessary for the load to reach the same height as it would without the pulleys. The magnitude of the force is reduced, but it must act through a longer distance. The effort needed to pull a load up is roughly the weight of the load divided by the number of wheels. The more wheels there are, the less efficient a system is, because of more friction between the rope and the wheels. Pulleys are one of the six simple machines.

It is not recorded when or by whom the pulley was first developed, but most likely came from Eurasia. The basic building block of a pulley, the wheel, was unknown to cultures in the western hemisphere, sub-Saharan Africa and Australia until relatively recent encounters with Eurasians. It is believed however that Archimedes developed the first documented block and tackle pulley system, as recorded by Plutarch.

The types of pulleys are

- Fixed (Class 1)

A fixed or class 1 pulley has a fixed axle. That is, the axle is "fixed" or anchored in place. A fixed pulley is used to redirect the force in a rope (called a belt when it goes in a full circle). A fixed pulley has a mechanical advantage of 1.

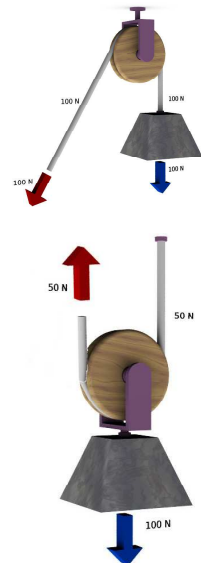
- Movable (Class 2)

A movable or class 2 pulley has a free axle. That is, the axle is "free" to move in space. A movable pulley is used to transform forces. A movable pulley has a mechanical advantage of 2. That is, if one end of the rope is anchored, pulling on the other end of the rope will apply a doubled force to the object attached to the pulley.

- Compound

A compound pulley is a combination fixed and movable pulley system.

- Block and tackle - A block and tackle is a compound pulley where several pulleys are mounted on each axle, further increasing the mechanical advantage. Plutarch reported that Archimedes moved an entire warship, laden with men, using compound pulleys and his own strength.



Mathematics

The ideal mechanical advantage (IMA) of a simple machine depends strictly on the geometry of the machine. This is the theoretical maximum mechanical advantage produced by a machine and is found by the ratio of input distance to output distance.

$$IMA = \frac{s_{in}}{s_{out}}$$

The actual mechanical advantage (AMA) of a simple machine is the ratio of output force to input force. This can be thought of as the produced by using the machine.

$$AMA = \frac{F_{out}}{F_{in}}$$

The efficiency (ϵ) of a machine is the ratio of energy output to energy input. It is also the ratio of AMA to IMA.

$$\epsilon = \frac{W_{out}}{W_{in}} = \frac{AMA}{IMA} = \frac{F_{out}s_{out}}{F_{in}s_{in}}$$