

BASIC MECHANICAL PRINCIPLES

THE SIX SIMPLE MACHINES

Author: Gunnar Nelson



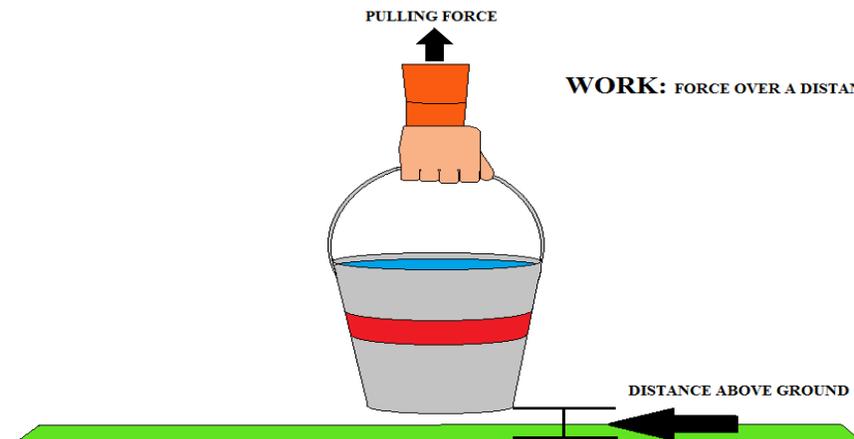
For those of you who are interested in mechanical devices, I'd like to introduce to you the six simple machines: **The lever, wheel & axle, pulley, inclined plane, wedge and screw.** It is helpful to understand how all of these things work as it will help you to understand how complicated machines work using the same principles.

IMPORTANT TERMS

Before we start talking about simple machines there are two important terms you will need to know:

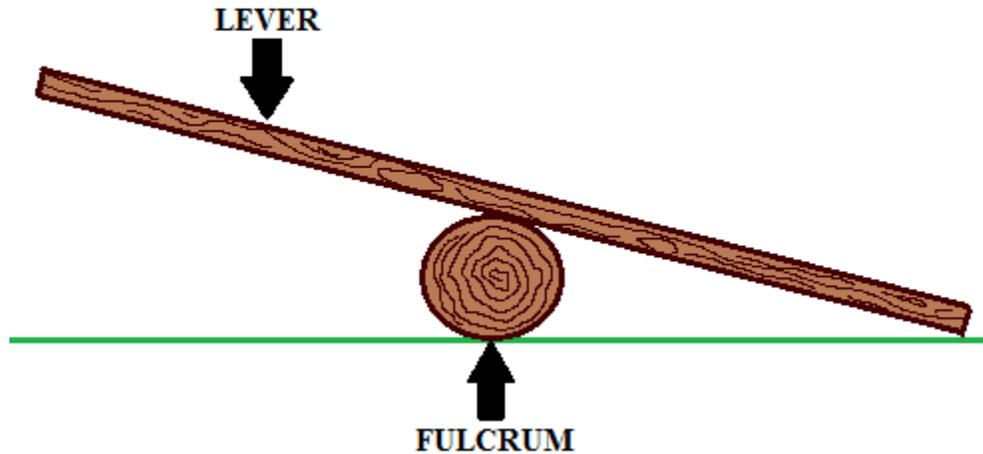
FORCE: Force can be a push or a pull. For example, if you pull on the handle of a wagon or cart you are exerting a pulling force. Also, if you push a door open, you are exerting a pushing force on the door.

WORK: Work is **force over a distance.** For example, lifting a bucket of water requires you to exert a pulling force on the handle to lift it off the ground. How far you lift the bucket off the ground is the distance. So, exerting a pulling force to move the bucket a certain distance off the ground is work.



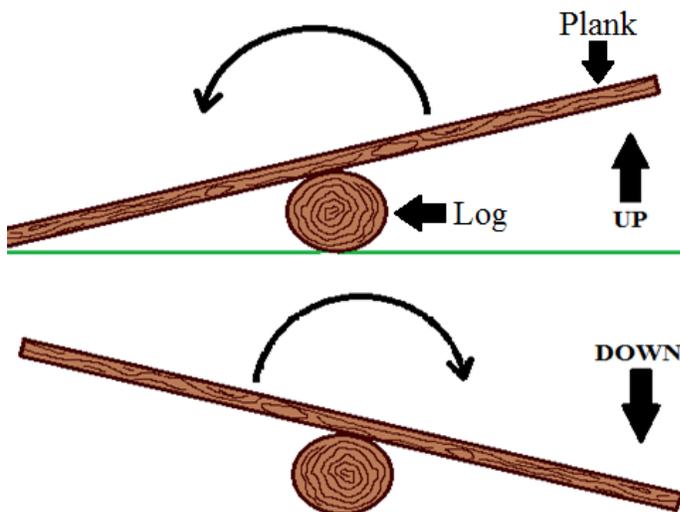
THE LEVER

The first machine I will explain is the lever. The lever is actually made up of two pieces: a **lever** (which could be a long, flat, wooden plank) and a **fulcrum** (which could be a round log or rock).



(As you can see in the drawing, the lever sits on top of the fulcrum.)

When the lever is on top of the fulcrum it is able to pivot from side to side. (See drawing below)



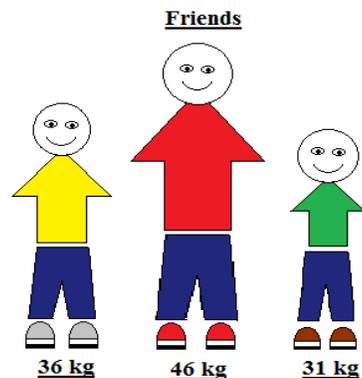
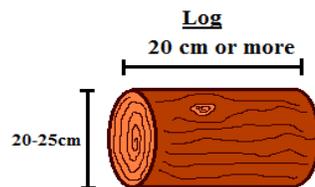
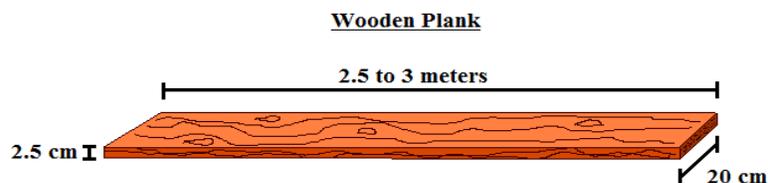
PIVOT: To pivot is to turn or rotate around a point. For example: The plank pivots on the log.

So far you're probably thinking "So what. So a lever can pivot around a fulcrum, what's so useful about that?" But a lever can be a very useful tool because it allows us to lift heavy objects with ease. To show you how this is possible, let's do a little experiment. First I'll give you some instructions on how to build a lever. Then I'll show you how to do the experiment.

THE EXPERIMENT

LIST OF THINGS YOU WILL NEED:

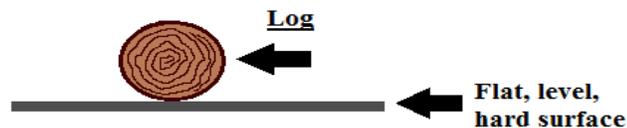
- 1 Wooden plank about **2.5 to 3 meters long**, at least **2.5 centimeters thick** and about **20 centimeters wide**.
 - 1 Round log (the more round the better) about **20-25 centimeters in diameter** and at least as wide as the wooden plank preferably wider.
- A group of friends who are all different sizes



Now that you have your materials you will need to put them together:

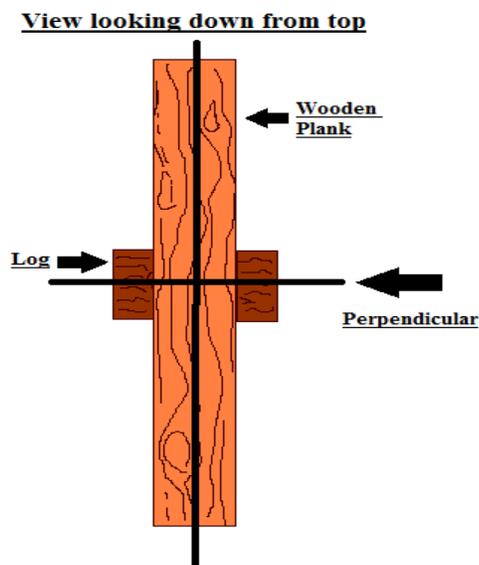
Step 1 First, find a flat, level, hard surface to place your log on.

NOTE: *make sure the log is securely in place and that it will not roll easily out of position. You may want to cut a flat spot into the bottom of the log or use a few heavy rocks around the base of the log to keep it from rolling*

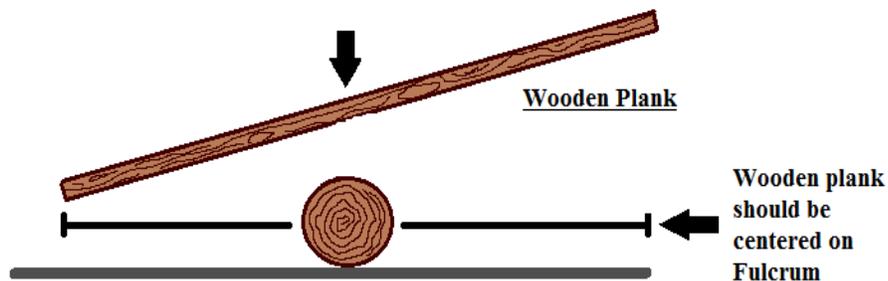


Step 2 Next, place your wooden plank on top of the log making sure they are Perpendicular.

NOTE: Perpendicular is when two lines intersect at a 90 degree angle. Perpendicular lines look like a plus sign +.

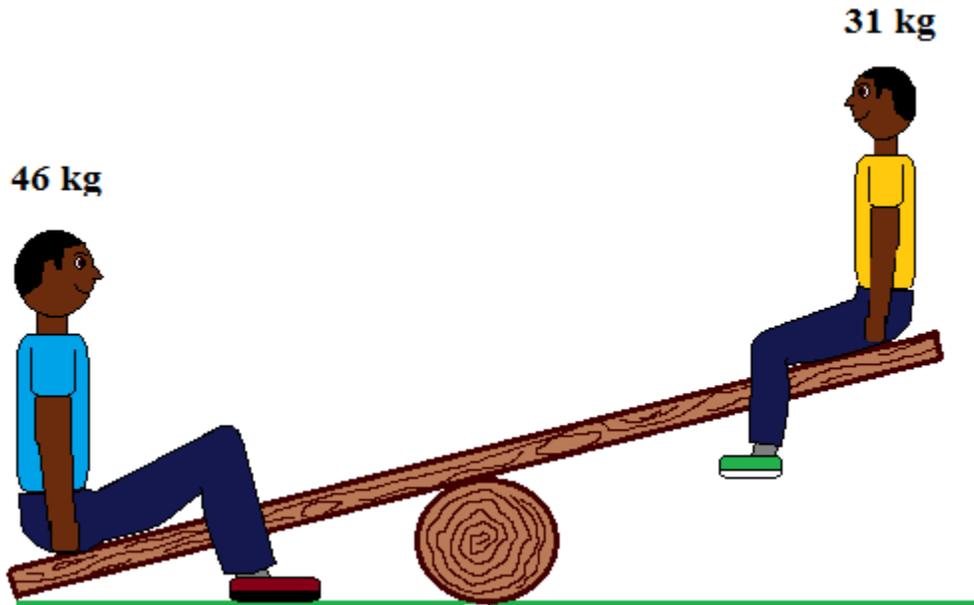


Step 3 Also, make sure the wooden plank is centered, lengthwise on the fulcrum.



Now that your lever is assembled we can begin the experiment:

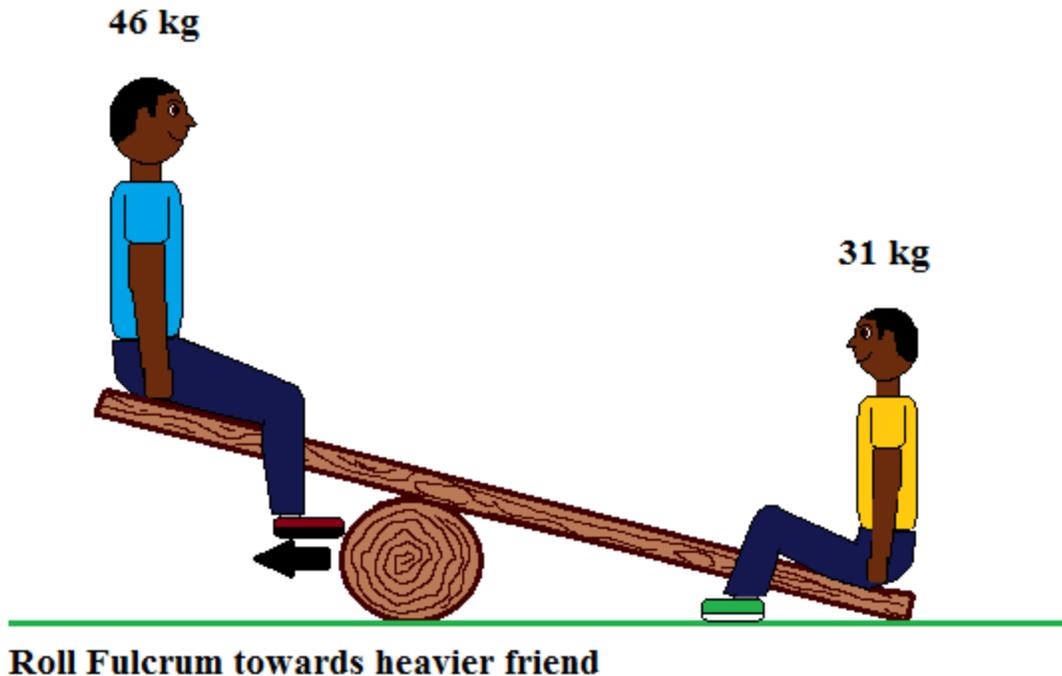
- 1.) From your group of friends, pick two who are very different in weight. (One much heavier than the other)
- 2.) Next, have them sit one at one end of the lever and one at the other end as shown in the picture below.



NOTE: (Notice that the lever is touching the ground on the side where the heavier friend is sitting and the lighter friend is off the ground.)

Now I'm going to show you how the lighter friend can lift the heavier friend off the ground!

- 1.) First, you will need your friends to get off the lever
- 2.) Then, roll the fulcrum closer to the side where the heavier friend will be sitting.
- 3.) Now, have your friends get back on the lever. (Remember to have the heavier friend sit on the side of the lever that the fulcrum is closest to)



NOTE: (You may have to experiment by moving the fulcrum around to find the correct position where the lighter friend will be able to lift the heavier friend.)

How is that possible? How could 31 kg lift 46 kg?

It's called: **MECHANICAL ADVANTAGE!**

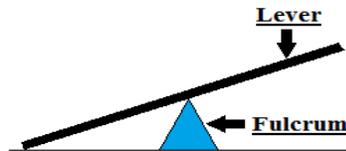
And it's what makes levers a very useful tool!

NOTE: (I'm going to end my explanation here because the theory of mechanical advantage gets complicated. However, if you are interested in learning more Wikipedia.com has a great explanation of Mechanical Advantage, The Law of the Lever and some mathematical equations related to mechanical advantage. Just copy and paste this link into the address bar on you internet browser: http://en.wikipedia.org/wiki/Mechanical_advantage)

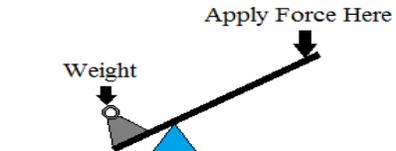
Let's sum up the important points about levers:

More Mechanical Advantage: If you are pushing down on one end of a lever, the closer the fulcrum is to what you are trying to lift, the less force you need to exert to lift it.

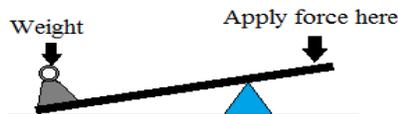
Less Mechanical Advantage: If you are pushing down on one end of a lever, the closer the fulcrum is to you *and* the further it is away from what you are trying to lift, the more force you have to exert to lift it.



Neutral Position: Fulcrum is equal distance from both ends of the lever



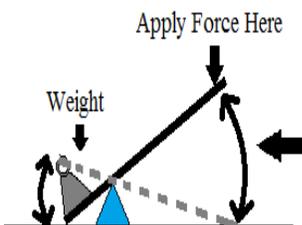
More Mechanical Advantage: The fulcrum is closer to the weight you are trying to lift than where you are applying force.



Less Mechanical Advantage: Fulcrum is further from the weight you are trying to lift and closer to where you are applying force.

There are some trade-offs to increasing mechanical advantage.

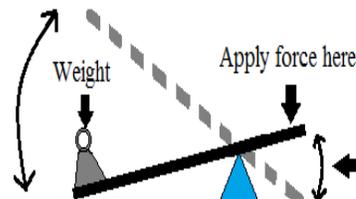
As you increase mechanical advantage you decrease the distance you are able to move the weight or the friend you are trying to lift



Notice how far you have to move the side you are pushing on to get the weight to move a small distance.

More Mechanical Advantage:

As mechanical advantage increases, the distance you are able to move the weight decreases.



Notice how you only have to move your end a little bit to get a lot of movement on the other end.

Less Mechanical Advantage:

Fulcrum is further from the weight you are trying to lift and closer to where you are applying force.

Here are some examples of levers that are used everyday:

PRY BARS



image taken from:
www.harborfreight.com

image taken from:
www.steritool.com

PLIERS

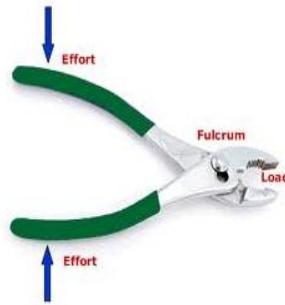


image taken from:
www.school-for-champions.com

OARS

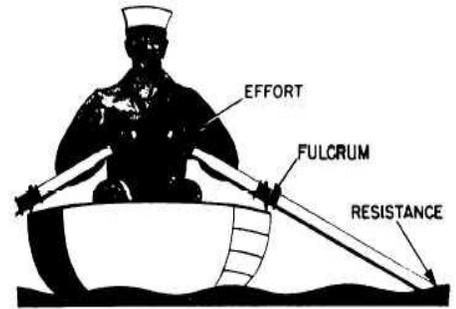


image taken from:
enginemechanics.tpub.com

BICYCLE PEDAL CRANKS



image taken from:
www.schoellerfamily.org

SCISSORS

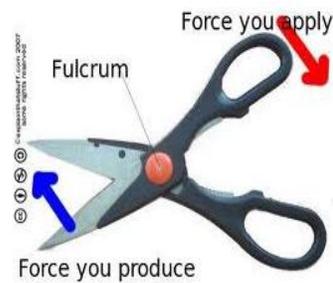


image taken from:
colinhansen.wordpress.com

WHEEL AND AXLE

"The simple machine called a *wheel and axle* refers to the assembly formed by two disks, or cylinders, of different diameters mounted so they rotate together around the same axis."

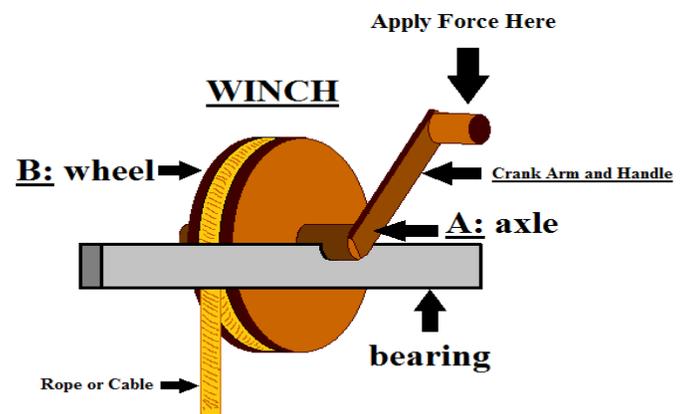
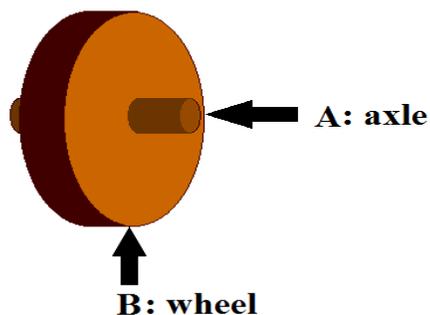
(Definition taken from: http://en.wikipedia.org/wiki/Wheel_and_axle)

There are several ways a wheel and axle can be used including:

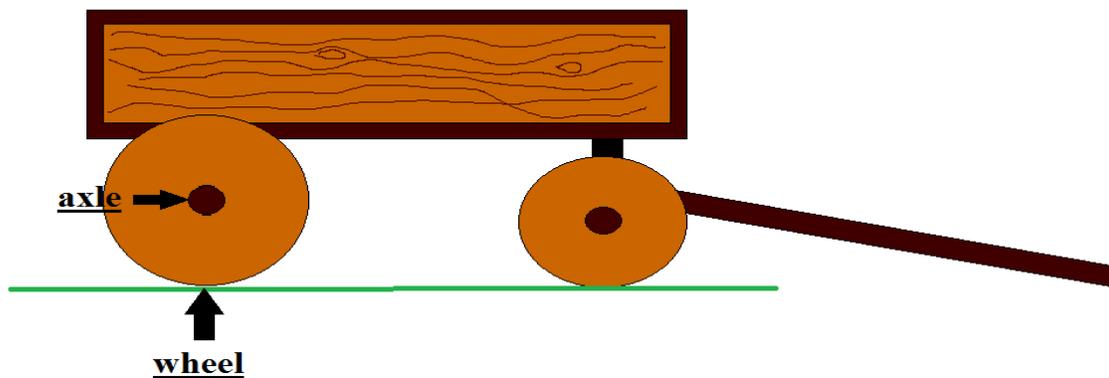
As a winch: The wheel has a groove running around its' circumference. A rope or cable is wound around the wheel in the groove. A crank arm and handle are attached to one end of the axle. As the wheel is rotated in one direction by applying force to the crank handle, the rope wraps around the wheel. Then, as the wheel is rotated in the opposite direction, the rope unwraps from the wheel. If a load is attached to the rope (let's say a bucket of water); if the wheel is rotated so that the rope wraps around it, the rope will lift the bucket. Then, if the wheel is turned in the opposite direction so that the rope unwraps, the bucket will be lowered.

On a wagon: The axle is attached to the bottom of the wagon and the wheel rotates on the axle.

WHEEL AND AXLE



WAGON



NOTE: The following internet link will take you to a video that explains wheels and axles in detail: <http://www.youtube.com/watch?v=P7xu9O0miEc>

Here are some examples of wheels and axles that you could see everyday:

AUTOMOBILE STEERING WHEEL



picture taken from:
msgirardsonlineclassroom.pbworks.com

PENCIL SHARPENER



image taken from:
www.angelfire.com

FERRIS WHEEL



image taken from:
www.ehow.com

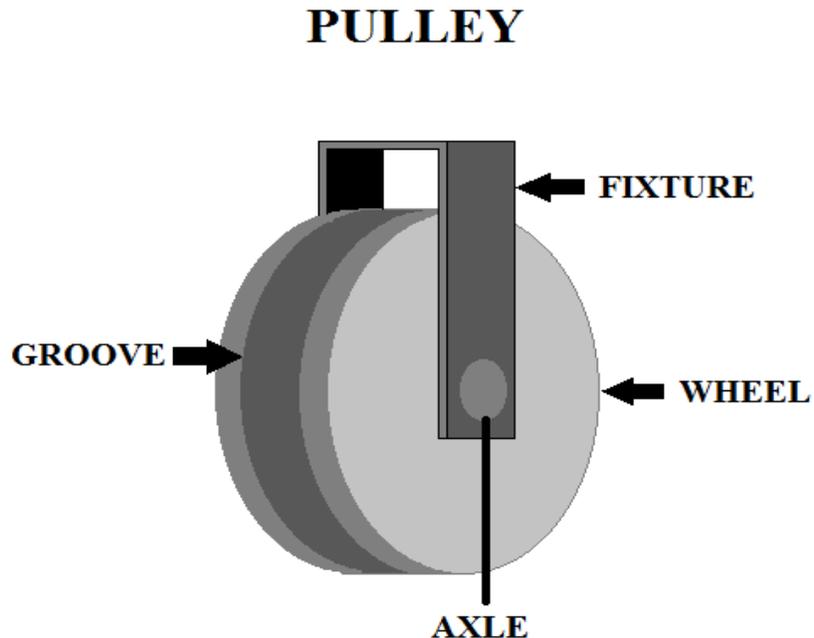
BICYCLE WHEEL



image taken from:
wheelworks.com

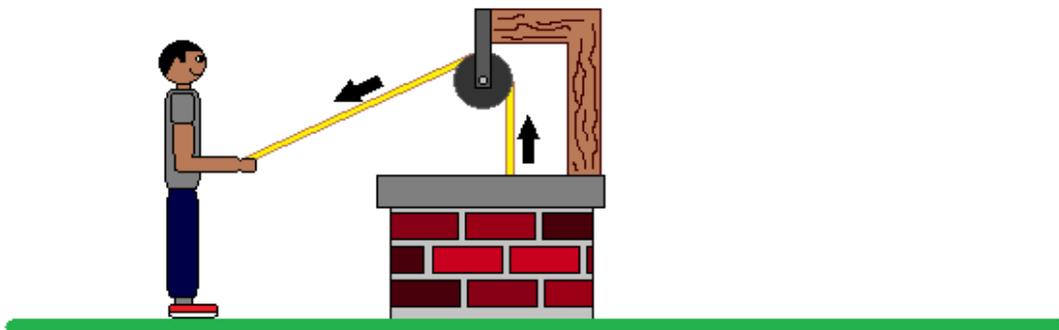
PULLEY

The pulley is very similar to the wheel and axle. It is made of a wheel (usually with a groove around its outer edge), the wheel typically rides on an axle and the wheel and axle is mounted in some sort of fixture. (See illustration below)



Pulleys are usually used with ropes, belts or cables running in their grooves. Used this way, the pulley allows the rope, belt or cable to change direction while transmitting force.

NOTICE HOW THE PULLEY CHANGES THE DIRECTION OF THE FORCE. THIS ALLOWS THE MAN TO STAND IN A COMFORTABLE POSITION AND RAISE SOMETHING UP OUT OF THE WELL.



Pulleys can also be used for mechanical advantage. To learn more about this just copy and paste the following link into the internet address bar: <http://www.youtube.com/watch?v=9T7tGosXM58>

Places you might find pulleys in action:

AUTOMOBILE ENGINES



image taken from:
www.rodauthority.com

SAILING SHIPS



image taken from:
www.cnn.com

CRANES



image taken from:
en.wikibooks.org

POWER TOOLS (Like this drill press)

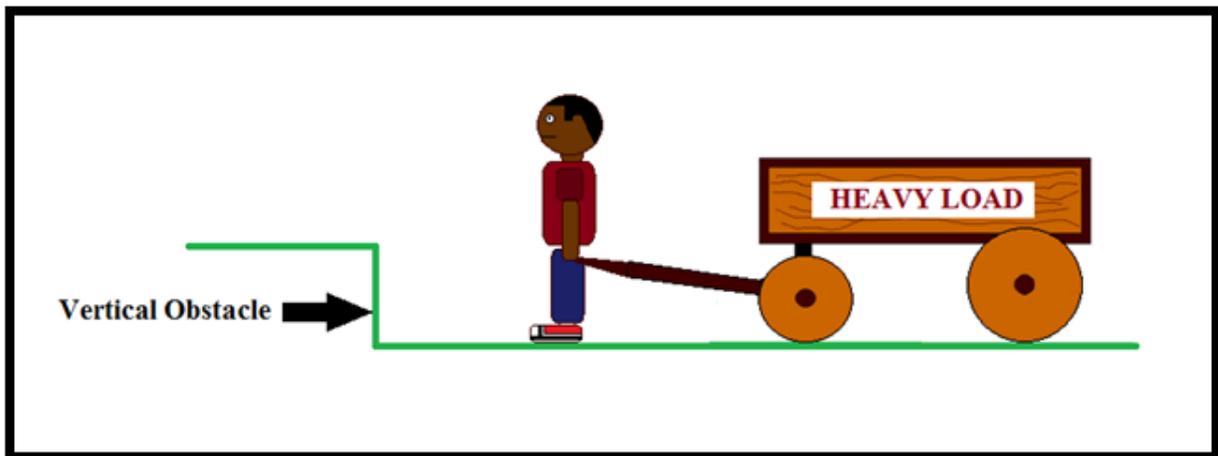


image taken from:
www.harborfreight.com

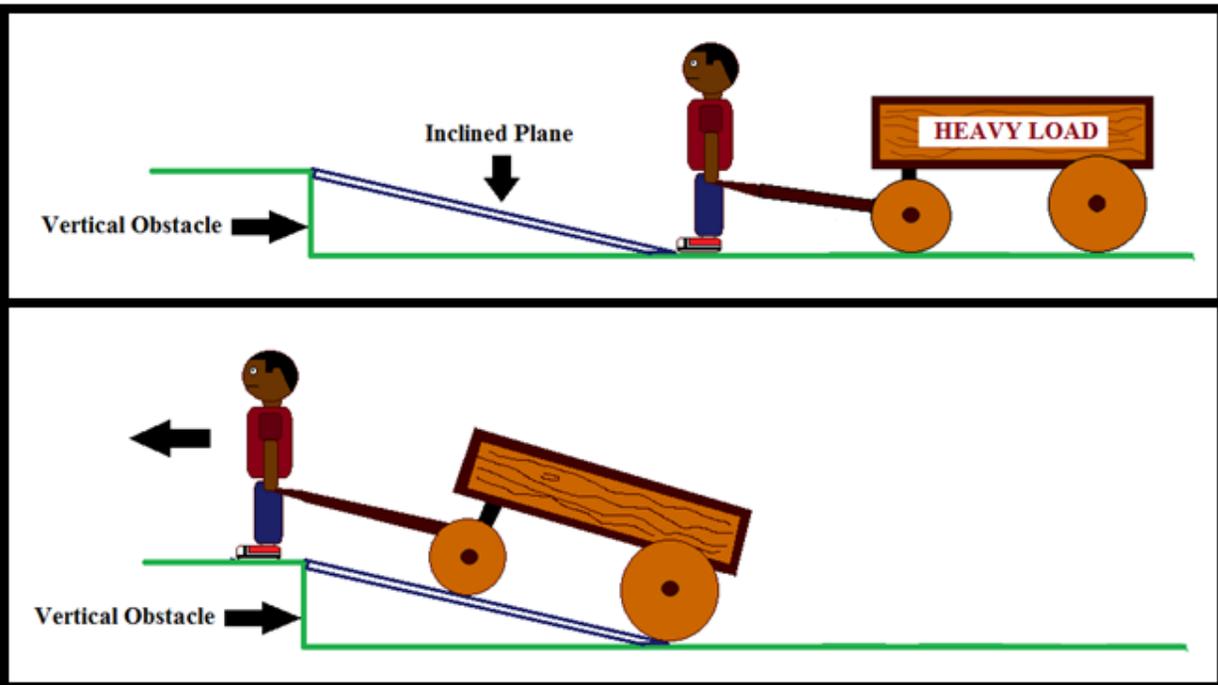
INCLINED PLANE

The inclined plane is different from the first three machines we have discussed as it does not move. An inclined plane is a flat surface that can be used to allow heavy loads to be moved over vertical obstacles. Another name for an inclined plane is **ramp**.

As you can see in the picture below, the man pulling the wagon cannot go any further because of the vertical obstacle.

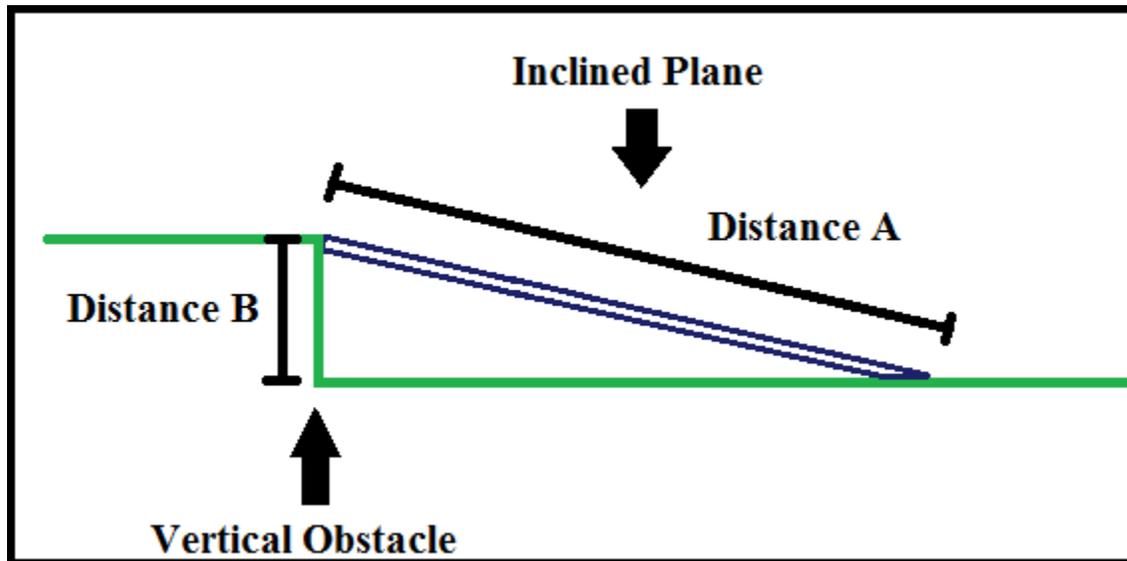


However, if he uses an inclined plane (ramp) it will allow him to travel over the vertical obstacle.



Like the lever, there are trade offs when using an inclined plane:

- * Using an inclined plane makes it possible to travel over vertical obstacles by creating a gentle slope to slowly lift the load, reducing the amount of force required to move it.
- * The trade off is that the inclined plane increases the distance the load has to travel. In the picture below: Distance A (length of inclined plane) is longer than distance B (the height of the vertical obstacle).



IMPORTANT POINTS ABOUT INCLINED PLANES:

- * The heavier the load you are trying to move, the longer the ramp you will need to move it over a vertical obstacle. (As the ramp gets longer, the slope becomes less steep)
- * Also, the taller the vertical obstacle, the longer the ramp you will need.
- * If your load is light and you are more interested in going the shortest distance possible, a shorter, steeper ramp can be used. This will increase the amount of force required to move the load but you will not have to travel as long a distance.
- * You don't just use inclined planes to go up hill; they can also be used to move heavy objects over sharp drop-offs. Without an inclined plane, the heavy load you are moving could fall and get damaged.

Here are some examples of inclined planes that are used everyday:

PLAYGROUND SLIDE



image taken from:
library.thinkquest.org

LOADING RAMP



image taken from: www.ehow.com

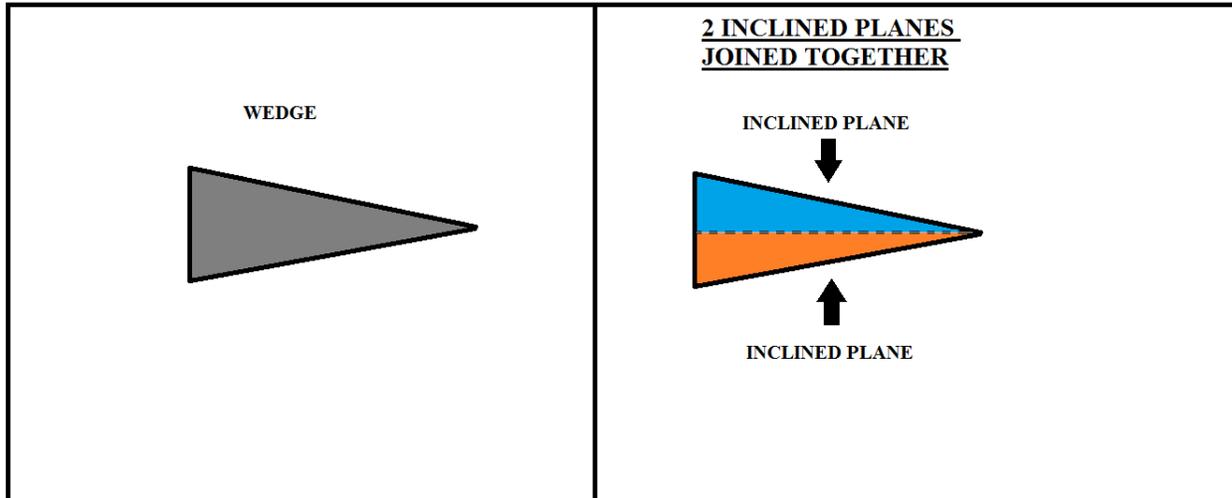
STAIRS



image taken from: denoxa.com

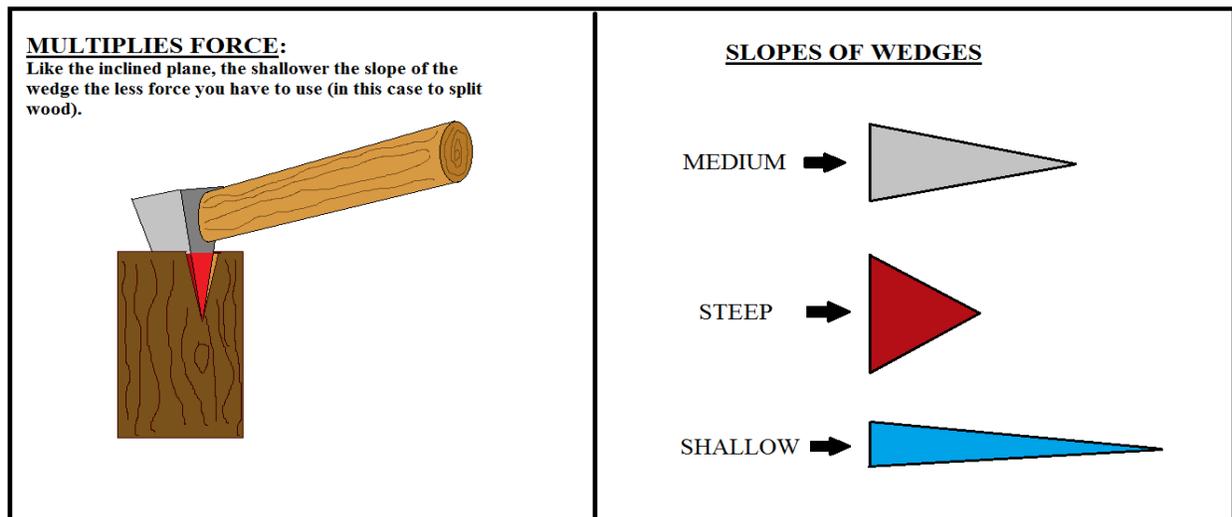
WEDGE

A wedge is basically two inclined planes that have been joined together. Typically wedges are used as tools for splitting. The most common wedge tool is the axe.



MULTIPLYING FORCE WITH A WEDGE:

Like many of the other simple machines, wedges are used to multiply force. By using a wedge with a shallow slope you can use less force to split an object (like a log). Like the other machines though, there is a trade off. You may use less force with a shallow slope wedge but you will have to move the wedge further. A steep slope wedge, on the other hand, will split a log in a shorter distance but it will require you to use much more force.



SO THE TRADE OFFS ARE:

- * LESS FORCE BUT LONGER DISTANCE (SHALLOW SLOPE)
- * MORE FORCE BUT SHORTER DISTANCE (STEEP SLOPE)

Examples of some common wedge tools:

DOOR STOP



image taken from:
www.selectchina.com

KNIVES



image taken from:
knives4business.com

AXES



image taken from:
https://www.google.com/shopping/product/3751151799287?q=axes&bav=on.2,or.r_qf.&biw=1600&bih=775&sa=X&eNemUdjHMsmpiQKY6oHIDA&ved=0CLkBEPICMAc

CHISELS



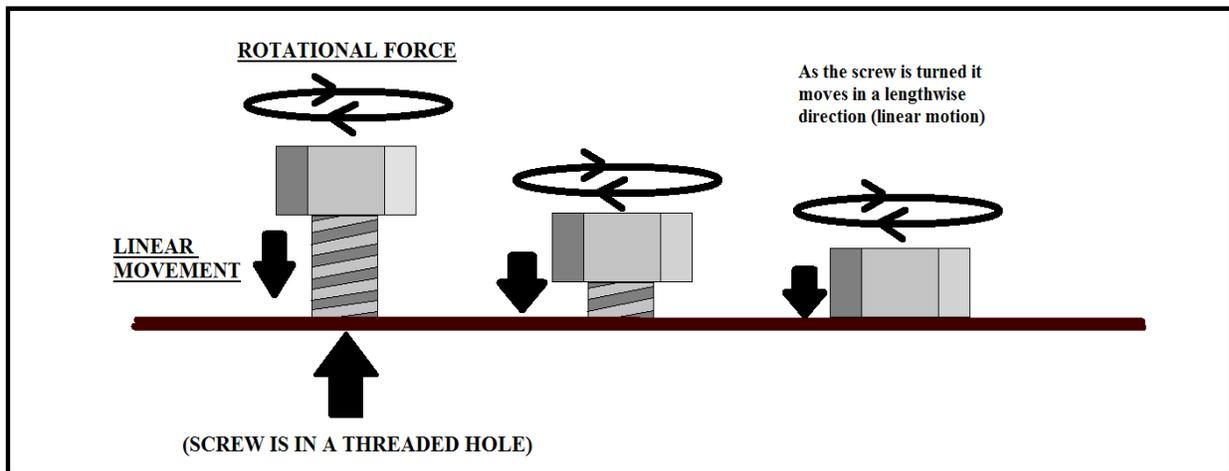
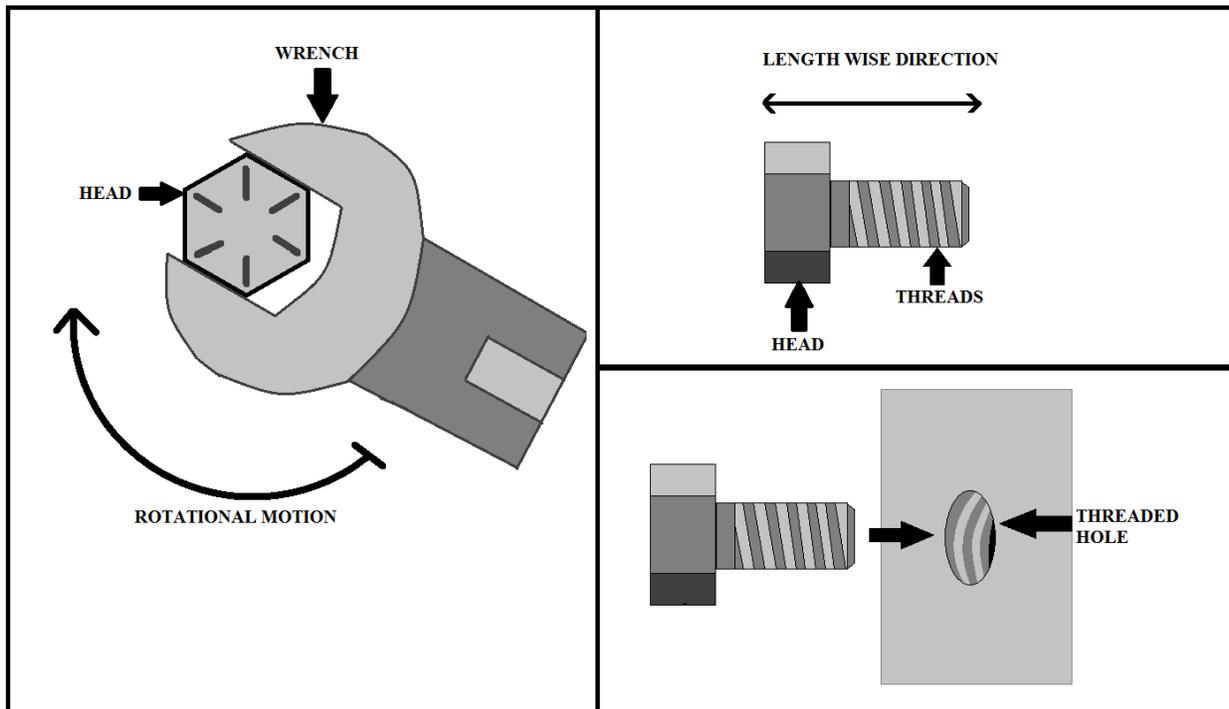
image taken from:
goawaygarage.blogspot.com

SCREW

"A **screw** is a (machine) that converts rotational motion to linear motion, and a torque (rotational force) to a linear force."

(Definition taken from: [http://en.wikipedia.org/wiki/Screw_\(simple_machine\)](http://en.wikipedia.org/wiki/Screw_(simple_machine)))

The definition for a screw that is given above probably sounds confusing because it uses a lot of big words. However, a screw works in a very simple way. Using a wrench, a screwdriver or even your fingers, you can turn a screw by applying force to the head. When the screw is in a threaded hole and turned in this way it will move in a lengthwise direction (see illustration below).



Examples of how screws can be used:

DIFFERENT TYPES OF CLAMPS

C-CLAMP
(NAMED FOR ITS SHAPE)



image taken from:
www.colourbox.com

HOSE CLAMP



image taken from:
www.sears.com

HAND SCREW
(TYPICALLY USED TO CLAMP WOOD)



image taken from:
www.amazon.com

DIFFERENT TYPES OF JACKS (LIFTING DEVICES)

SCISSOR JACK



image taken from:
grabcad.com

BASE SCREW JACK



image taken from:
www.made-in-china.com

MECHANICAL SCREW JACK



image taken from:
www.forceresources.com

ARCHIMEDES SCREW USED AS A WATER PUMP

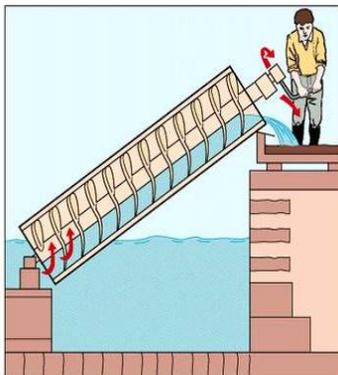


image taken from:
www.archimedeshydrocrew.com



image taken from:
hydrovolts.blogspot.com

CORK SCREWS USED TO REMOVE CORKS FROM WINE BOTTLES



image taken from:
eofdreams.com



image taken from:
en.wikipedia.org

To learn more about how the Archimedes Screw works, just type this link into your internet browser bar: <http://www.youtube.com/watch?v=A-xPRbj88V4>