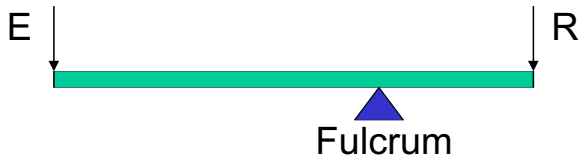
Activity 1.1a - All About Simple Machines

Purpose

Any mechanical device that humans use is made from six basic building blocks called simple machines. A simple machine will increase force output by decreasing direction output or can decrease force output by increasing direction output. It's important to note that when a simple machine is used the same amount of work is required - it just seems easier. A simple machine reduces the amount of effort needed to move an object, but it results in moving it a greater distance to accomplish the same amount of work. All complex mechanisms are made from simple machines.

The Lever

The lever is the first of the simple machines and consists of a lever arm and a fulcrum.



Effort (E) is the input force which must be supplied by the user or an engine of some kind.

Load (R) is the output force which is also the force resisting motion.

Lever Concepts:

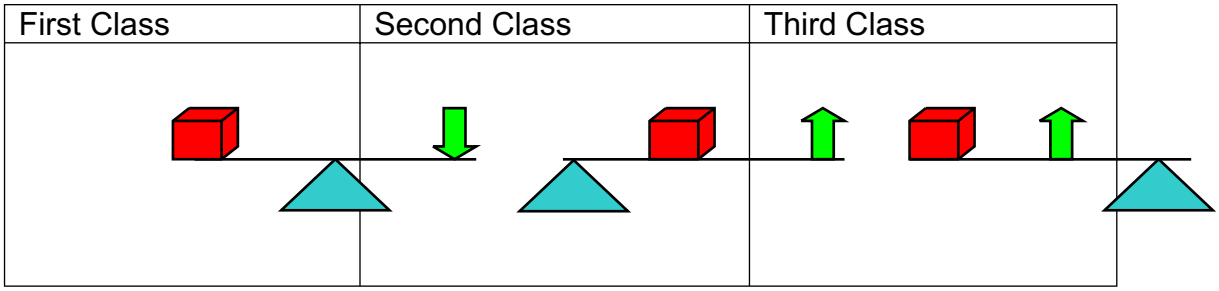
- Force applied to a body
- Distance from fulcrum to weight
- Distance from fulcrum to forces
- Support on which the lever rests
- The object to be moved

Types of levers

First class lever: The fulcrum is located in the center of the lever arm and the effort and load are at opposite ends. Example Seesaw

Second class lever: With a second-class lever the weight is located in the middle and the fulcrum and the effort or at opposite ends. Example Wheelbarrow

Third class lever: The effort is applied at the middle of the arm and the weight is held at one end while the fulcrum is at the other end.



1. List examples of each class of lever by constructing a table below.

	Class I	Class II	Class III
1	Crowbar	Crowbar	Atlatl
2			
3			

Equations:

1) The first equation shows the formula for calculating the Mechanical Advantage for a Lever:

$$\text{Mechanical Advantage (M.A.)} = \frac{\textbf{L}\text{ength from Fulcrum to }\textbf{E}\text{ffort}}{\textbf{L}\text{ength from Fulcrum to }\textbf{L}\text{oad (}\textbf{R}\text{)}} = \frac{\textbf{LE}}{\textbf{LR}}$$

2) The second equation calculates the Load (R) that can be moved if one knows the Effort (E) and the Mechanical Advantage (M.A.):

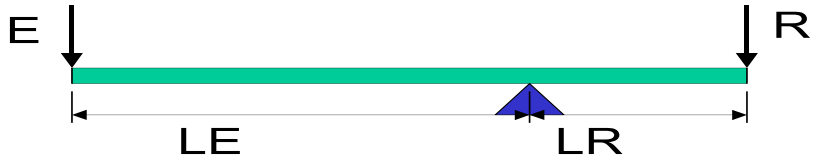
$$\text{Load} = \text{Mechanical Advantage times Effort}$$
$$\text{Or}$$
$$R = \text{M.A.} * E$$

3) The second equation can be manipulated algebraically to find the Effort needed if one knows the Load (R) and the Mechanical Advantage (M.A.):

$$\text{Effort (E)} = \frac{\text{Load (R)}}{\text{Mechanical Advantage}} = \frac{R}{\text{M.A.}}$$

Lever Practice Problems

2. Using the diagram below and the equations discussed earlier, fill in the missing spaces on the table below. Show all work on a separate sheet of paper.

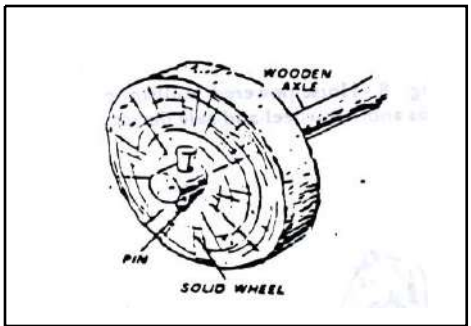


Load (R)	Resistance Arm (LR)	Effort Arm (LE)	Effort (E)
	2 feet	6 feet	1 lbs.
8 lbs.		4 feet	4 lbs.
13 lbs	2 feet		4 lbs.
50 lbs.	3 feet	5 feet	
113 lbs.	2 feet		40 lbs.
	1 foot	10 feet	1 ton

3. Select an example of a lever that you have in your home and how it is used to help make it easier to do the work.

4. Name five devices that use the principles of a lever and indicate the class of the lever.

5. If you were unable to move an object using an effort arm that was 5 feet long, would increasing the length of the effort arm help? Explain.

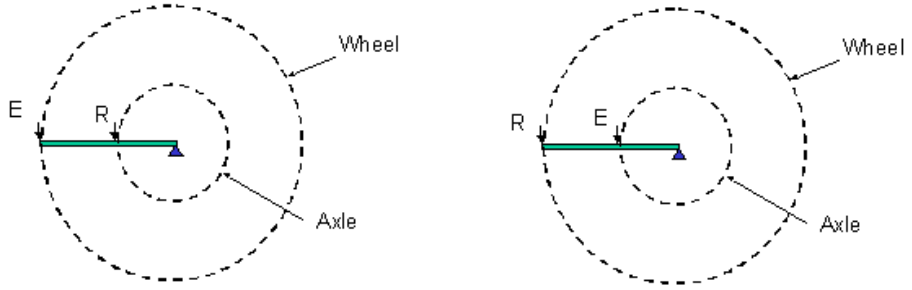


The Wheel & Axle

A wheel & axle is similar to a rotating lever. The wheel and axle can also be used to change from rotary to linear motion. By increasing the diameter of the wheel, the linear distance traveled for one revolution of the axle can be increased. A wheel & axle can be made from a 2nd or 3rd class lever.

Equations and Definitions:

1) The first equation shows the formula for calculating the Mechanical Advantage for a Wheel and Axle:



$$M.A. = \frac{\text{Radius to Effort}}{\text{Radius to Load}} = \frac{LE}{LR}$$

2) The second equation finds Resistance if the Effort and Mechanical Advantage are known:

$$\text{Resistance} = M.A. * \text{Effort}$$

3) The third equation is obtained by algebraically manipulating equation #2 above:

$$\text{Effort} = \frac{\text{Resistance}}{M.A.}$$

4) **Torque** is a twisting force. The units for torque are typically ft-lbs or inch-lbs. Torque can be calculated using the formula:

$$\text{Torque} = \text{force} * \text{radius}$$

5) **Rotary Motion** is the circular motion which occurs when the wheel and axle are rotated about the centerline axis. Usually rotary motion is defined in terms of degrees of revolution.

6) **Linear Motion** is the straight-line motion which occurs when a wheel rolls along a flat surface. The linear distance traveled when the wheel completes one revolution is equal to the circumference of the wheel.

$$\text{Circumference} = \text{Pi} * \text{Wheel diameter}$$

b

Wheel and Axle Practice Problems

1) A wheel is used to turn a valve stem on a water valve. If the wheel radius is 1 foot and the axle radius is .5 inches, what is the mechanical advantage of the wheel and axle?

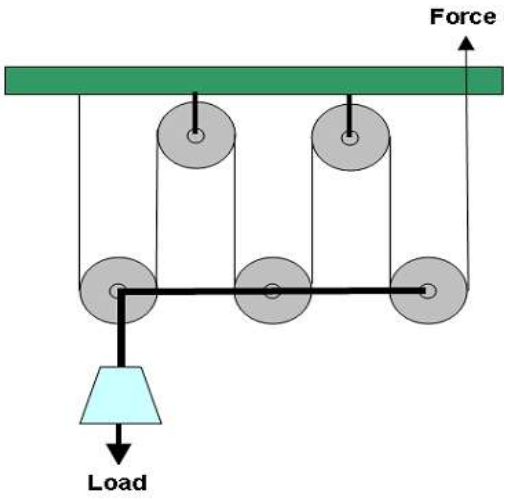
2) How much resistance force can be overcome when an effort of 80 lbs is applied to the wheel of the water valve in problem 1?

3) What is the linear distance traveled when a 2.5' diameter wheel makes one revolution?

4) On an automobile how could you increase the distance traveled for each revolution of the axle while keeping bearing friction constant?

The Pulley

A pulley is an adaptation of a wheel and axle. A single pulley simply reverses the direction of a force. When two or more pulleys are connected together, they permit a heavy load to be lifted with less force. The trade-off is that the end of the rope must move a greater distance than the load.



Concepts:

Effort
Force applied
Direction change

1) The first equation is the formula for calculating the Mechanical Advantage for a Pulley:

M.A. = Total number of strands supporting the load

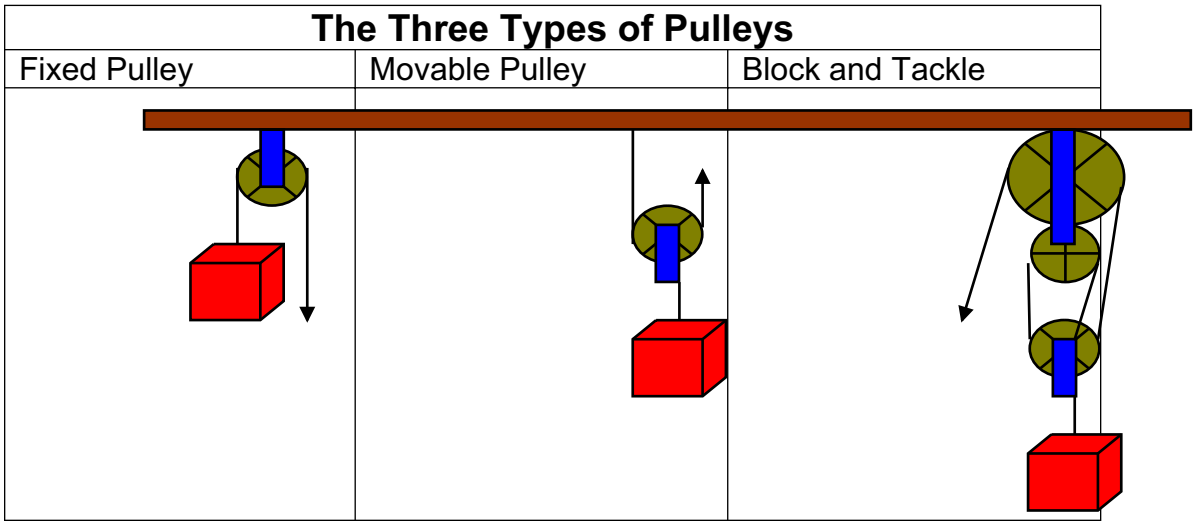
(Note: Count the end strand only when the effort is pointed upwards. For Example – for the diagram shown above the Mechanical Advantage is 6.)

2) The second equation finds the Load if Effort and Mechanical Advantage are known:

$$\text{Load} = \text{M.A.} * \text{Effort}$$

3) The third equation is obtained by algebraically manipulating equation #2 above:

$$\text{Effort} = \frac{\text{Load}}{\text{M.A.}}$$



A **Fixed Pulley** is defined when a pulley is attached or *fixed* to a strong member, which will not move. When a fixed pulley is used the force needed to lift a weight does not change.

A **Movable Pulley** splits the work in half. The effort needed to lift 180 pounds weight is 90 pounds. The mechanical advantage of a movable pulley is 2.

The **Block and Tackle** is a system of three pulleys. It reverses the direction of the effort so that a downward pull can be used to lift an object. The mechanical advantage is 3 so that 40 pounds of effort is needed to lift an object weighing 120 pounds. (The distance of the rope pulled is tripled.)

Pulley Practice Problems

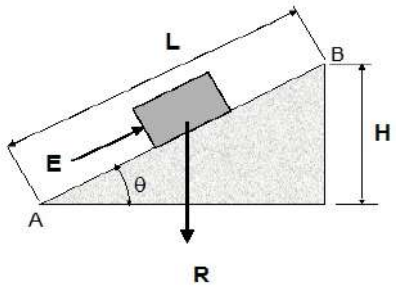
1) Using a block and tackle pulley system, determine the number of strands that will be needed to lift a weight of 1092 lbs. by applying 80 pounds of force.

2) Using a block and tackle pulley system, with 7 strands and an input force of 45 pounds, what is the maximum weight that can be lifted?

3) A climber is raising herself using the following system: A rope, secured to her harness passes over a pulley 50 meters above her and comes back down to her hands. What is her mechanical advantage if any? How high can she raise herself before stopping? Draw a diagram depicting the beginning and the end of this situation.

The Incline Plane

An inclined plane is a flat sloping surface along which an object can be pushed or pulled. An incline plane is used to move an object upward to a higher position.



Concepts:

The secret of the incline plane is that it splits the inclined resistance force into two components: A horizontal resistance force and a vertical resistance force (gravity). The effort only needs to overcome the horizontal component of the resistive force, since the plane supports the vertical force.

Equations and Definitions:

1) The first equation yields the Mechanical Advantage for the Incline Plane:

$$M.A. = \frac{\text{Length}}{\text{Height}} = \frac{L}{H}$$

2) The second equation finds the Load if Effort and Mechanical Advantage are known:

$$\text{Force} = M.A. * \text{Effort}$$

3) The third equation is obtained by algebraically manipulating equation #2 above:

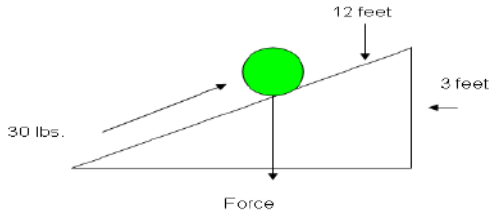
$$\text{Effort} = \frac{\text{Force}}{M.A.}$$

Incline Plane Practice Problems

1) Using the diagram below find the force and mechanical advantage. Be sure to show your work.

Mechanical Advantage =

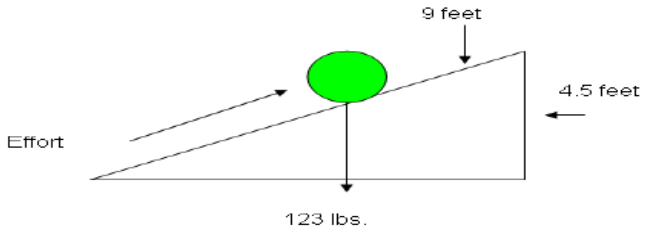
Force =



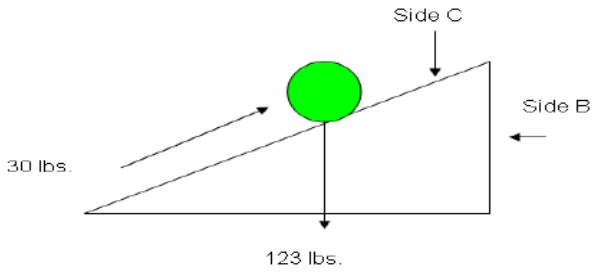
2) Using the diagram below find the mechanical advantage and effort needed to move the object up the inclined plane. Be sure to show your work.

Mechanical Advantage =

Effort =



3) With the given information, calculate the angle (in degrees) of the incline plane. (Show all work) Hint: use trigonometry



4) A group of skateboarders were trying to build a ramp with a height of 2.0 meters. They were short on wood so they decided to use drywall that they found in the trash instead. The length of the completed ramp was 3.6 meters. What was the MA of this ramp?

5) The first skater attempted a jump with 540 degrees of rotation, landing backwards. However, the ramp broke and skater fell on his head. The paramedics had to use an inclined plane in order to get the skater into the ambulance. They had to push the skater's heavy 290 pound body up the 8.1 meter long inclined plane. If the mechanical advantage of the inclined plane that was used is 6.0, how high from the ground was the ambulance?

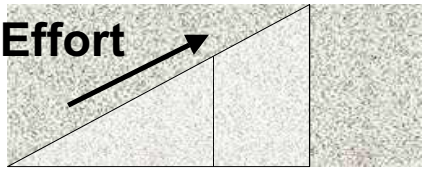
6) How much effort did the EMT's need to push the chubby skater into the ambulance?

The Wedge

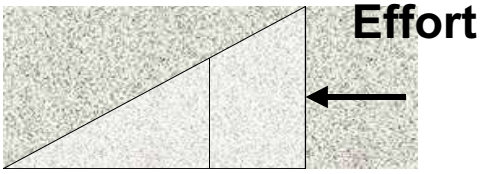
The wedge is a modification of the inclined plane. Wedges are used to separate or hold devices.

There are two major differences between inclined planes and wedges. During its use, an inclined plane remains stationary, while the wedge moves. With an inclined plane the effort force is applied parallel to the slope of the incline. With a wedge the effort force is applied to the vertical edge (height) incline of the wedge itself.

Wedge -Comparison to the Inclined Plane

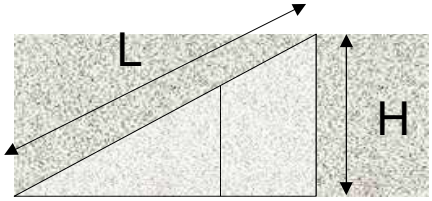


Inclined Plane

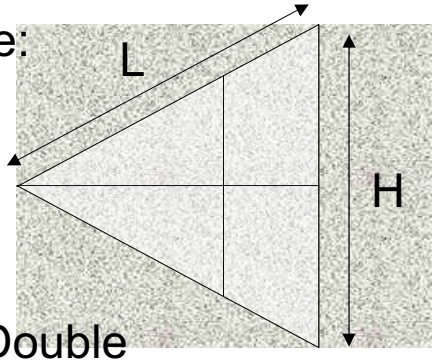


Wedge

Wedges can be single or double:



Single



Double

Equation: (Notice the similarity to those of the inclined plane):

1) The Mechanical Advantage for the Wedge is similar to that of the inclined plane:

$$M.A. = \frac{\text{Length}}{\text{Height}} = \frac{L}{H}$$

1) The second equation finds the Load if Effort and Mechanical Advantage are known:

$$\text{Force} = M.A. * \text{Effort}$$

2) The third equation is obtained by algebraically manipulating equation #2 above:

$$\text{Effort} = \frac{\text{Force}}{M.A.}$$

1) What is the mechanical advantage of a wedge that is one foot long and 3 inches high?

2) Using this wedge to split a log requires a force of 40 Newtons. What is the effort ?

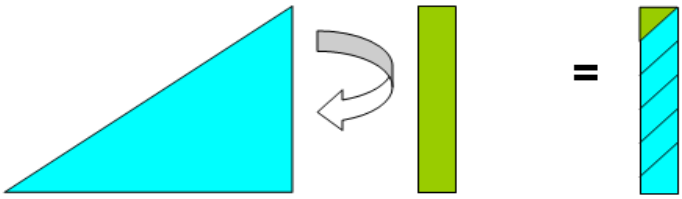
3) What is the required length of a 4 inch wedge if it is engineered to deliver a force six times greater than the effort?

4) What is the mechanical advantage of a wedge with a length to height ratio of 5?

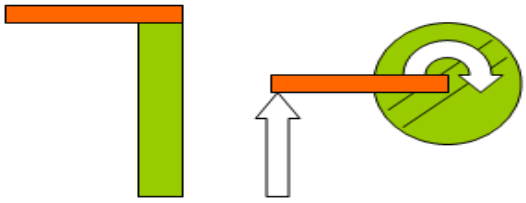
The Screw

A screw is a combination of two other simple machines:
1) An inclined plane (wrapped around a cylinder)
2) A wheel and axle

1) An inclined plane (wrapped around a cylinder):



2) A wheel and axle:



Equations and Definitions:

1) The **screw** can be used to change from rotary to straight line (linear) motion.

2) **Screw Pitch** is the distance between two adjacent threads on a screw. The formula to calculate pitch is:

$$\text{Pitch} = \frac{1}{\text{Number of threads per inch of length}}$$

3) The **Circumference** of the screw is calculated using the Geometry formula:

$$\text{Circumference} = \text{Pi} * \text{Diameter}$$

4) The formula for the Mechanical Advantage of a screw is:

$$\text{Mechanical Advantage} = \frac{\text{Circumference}}{\text{Pitch}}$$

Screw Practice Problems

Visit **http://www.wikihow.com/Read-a-Screw-Thread-Callout** to answer the first two questions. Also, there's a link to the site on Mr. Bayer's homepage.

1) How many threads are on a screw with a call out of 1/4-20? What is its largest diameter in inches?

2) How many threads are on a screw with a call out of #4-40 x .5? What is its largest diameter in inches?

3) **Metric screws/bolts** start with the letter M to indicate metric. The first number is the outside diameter in mm, the second number is the distance between threads in mm, and the third number (optional) is the length of the screw/bolt in mm. With this in mind, what is the thread spacing on a screw with a call out of M3 x 0.5 x 10? What is the outside diameter of the threaded region? How long is this screw?

4) Why do screw heads have a larger diameter than the screw shaft? Why is it easier when you use a screwdriver (other than getting a better grip)?

5) What is the mechanical advantage of a 3/8" diameter screw with a pitch of 20 threads per inch **IF** a 1.5" diameter screwdriver is used to install the screw?

Check this site out for more info:

1) **http://www.edheads.org/activities/simple-machines/**