Model Design & Building Merit Badge

Simple Machines

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Simple Machines

Simple machines are basic mechanical devices from which more complex machines are made

- The Mechanical Model for this Merit Badge should illustrate the use of 2 or more simple machines

There are 6 simple machines

- Lever
- Wheel and axle
- Inclined plane
- Pulley
- Screw
- Wedge

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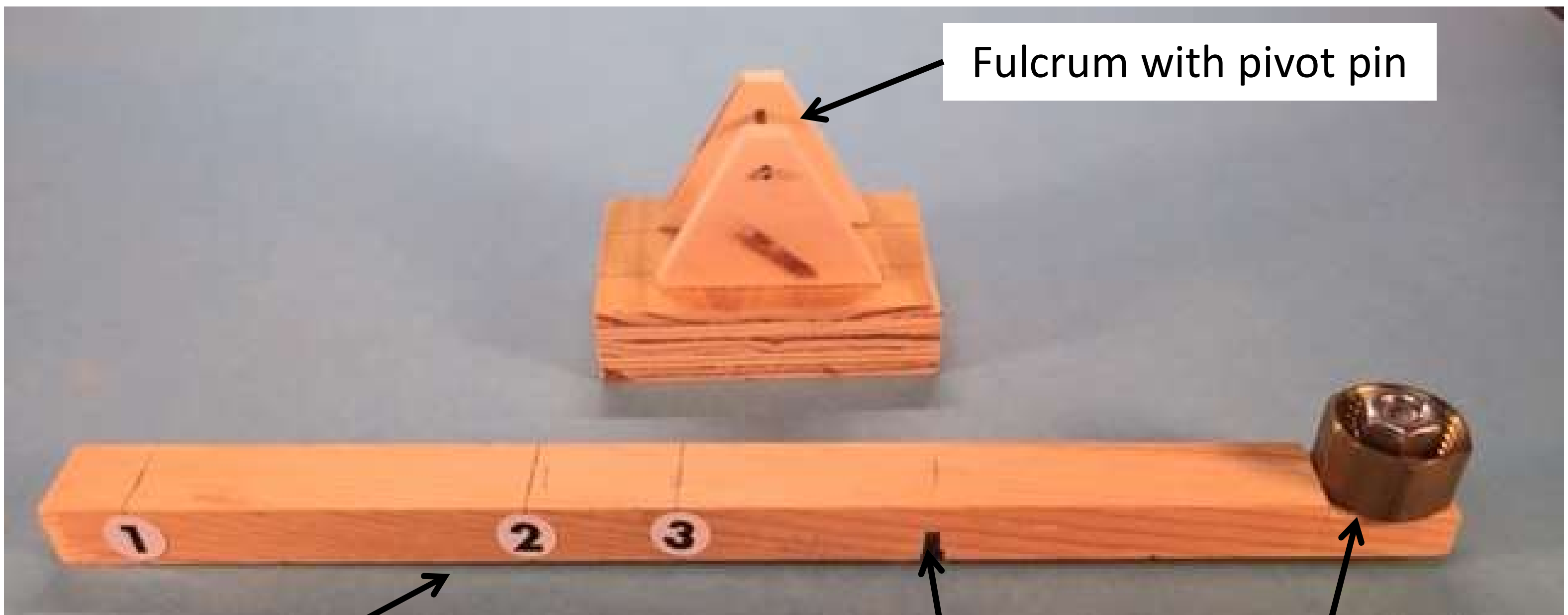
Simple Machines - Lever

A lever is a machine consisting of a bar and a pivot or fulcrum used to increase an applied force



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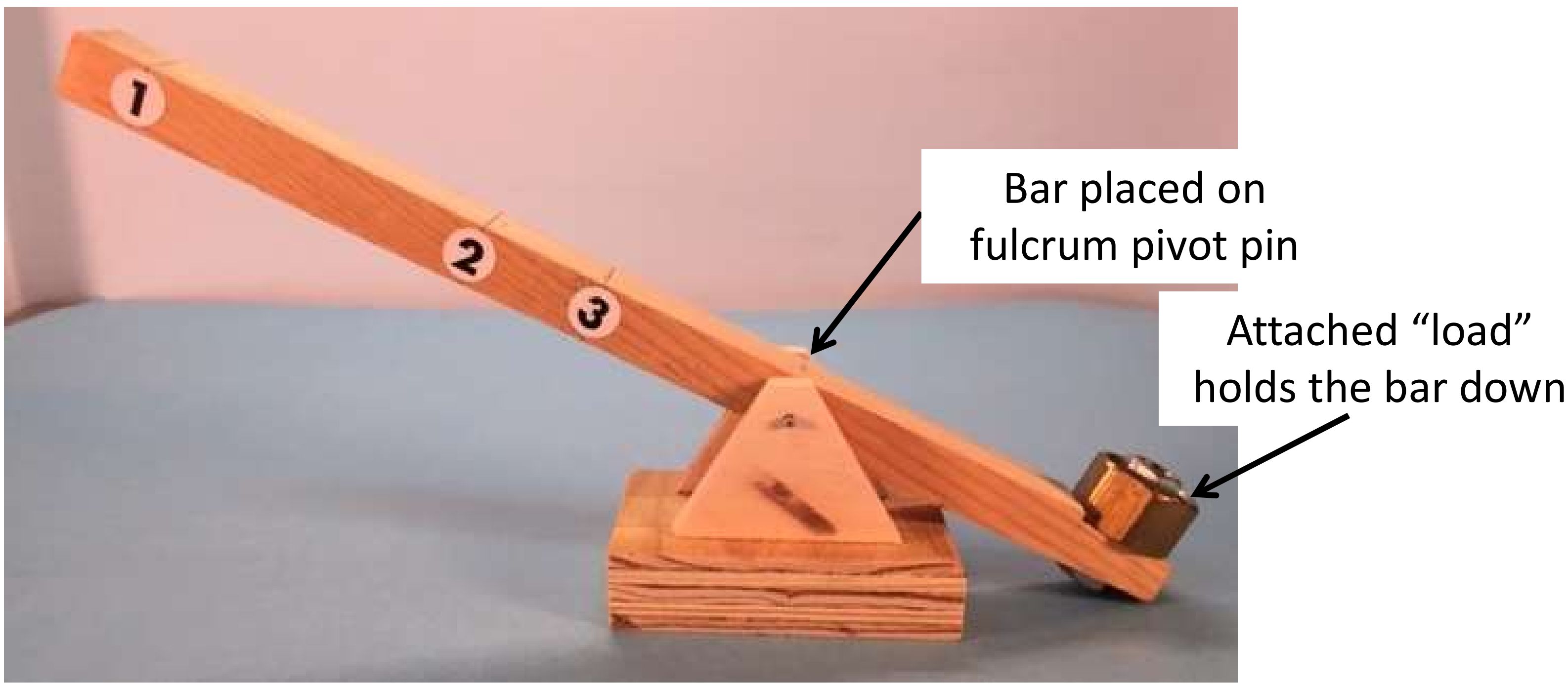
Simple Machines - Lever

The assembled lever:



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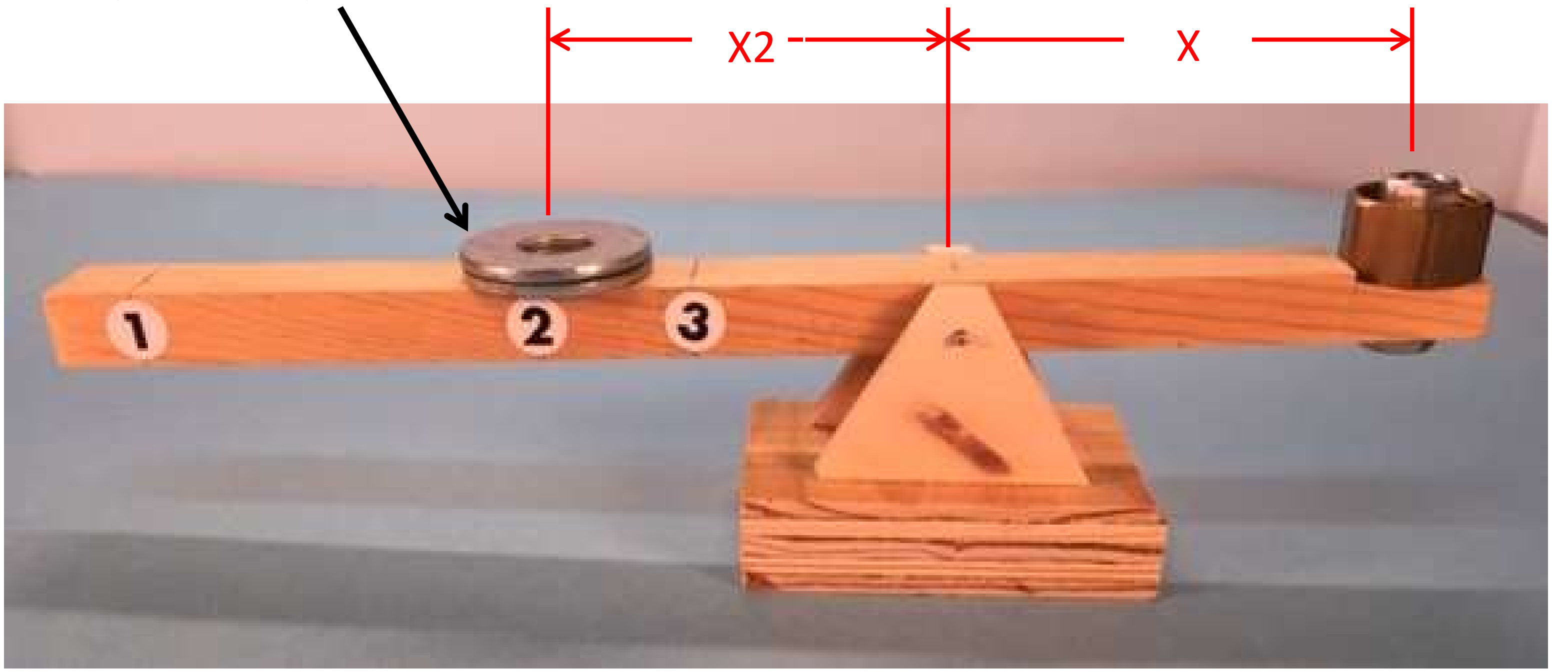
Simple Machines - Lever

Add weights (a force) to the left side of the bar:

Two large washers weighing the same as the "load" placed at point 2 balance the "load"



Most text books assume the bar has no mass, so X2 and X would be equal.
In a real object the bar does have mass, so X2 is a little less than X.

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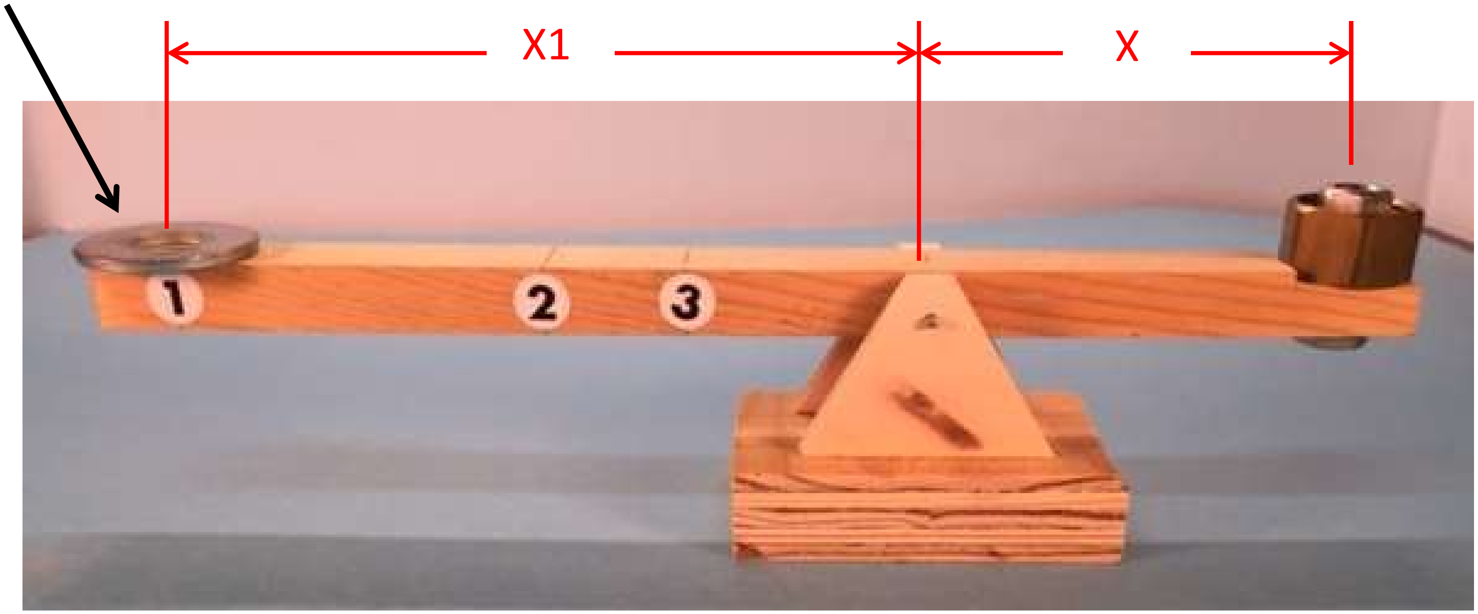
Simple Machines - Lever

Add weight (a force) farther from the pivot point to the left side of the bar:

One large washer weighing half as much as the "load" placed at point 1 balances the "load"



This demonstrates that a smaller weight or force placed farther from the pivot point can balance the weight or load

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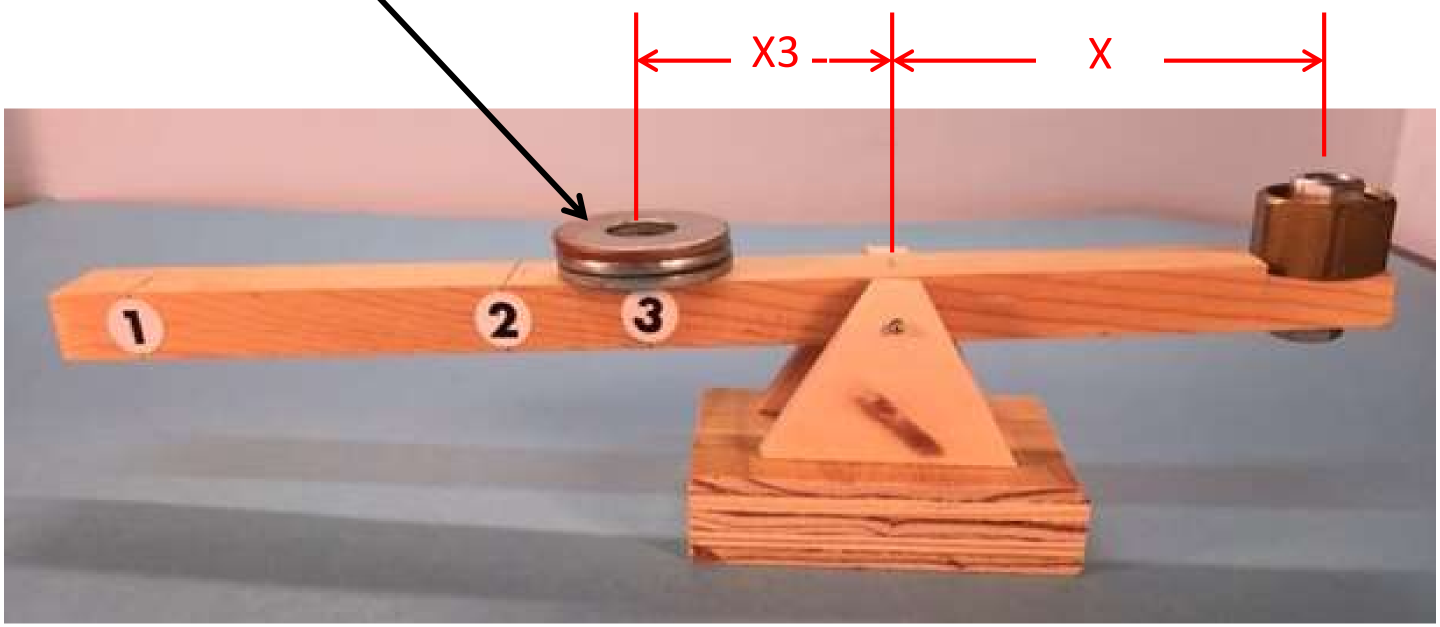
Simple Machines - Lever

Add weight (a force) closer to the pivot point to the left side of the bar:

Three large washers weighing 1 ½ times as much as the “load” placed at point 3 balances the “load”



This demonstrates that a larger weight or force must be placed closer to the pivot point to balance the weight or load

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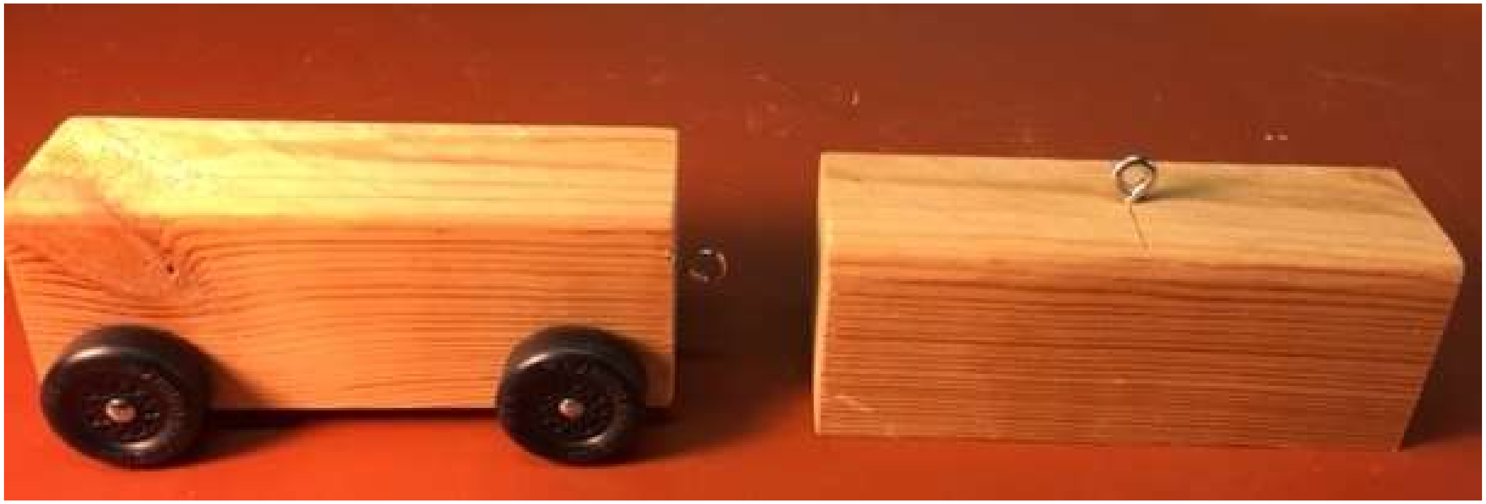
Simple Machines – Wheel and Axle

A round wheel or wheels mounted to an axle enables an object to be moved with much less force than by pushing or dragging the object

Let us consider two identical blocks, one equipped with wheels and one set flat:



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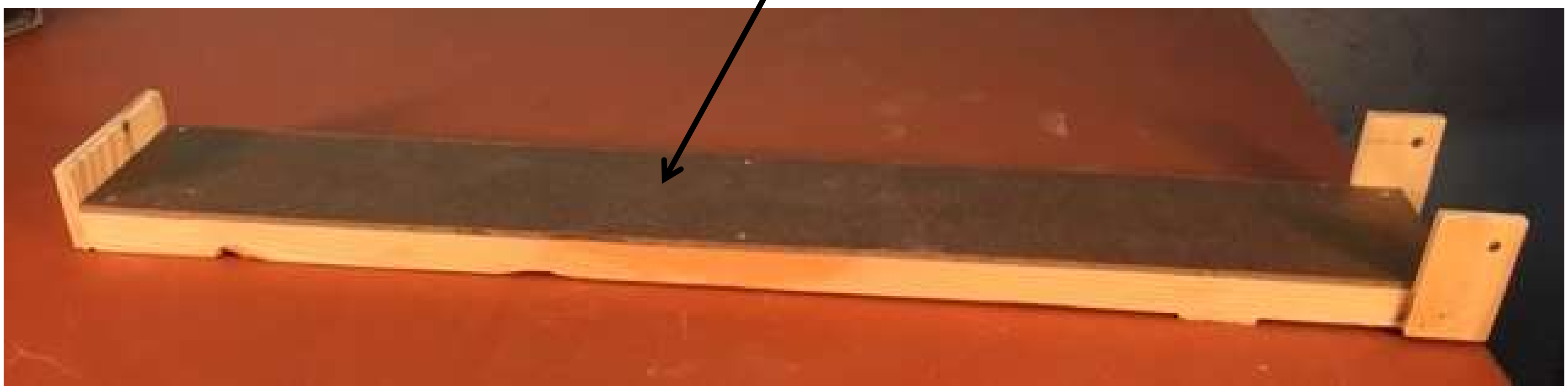
Simple Machines – Wheel and Axle

We'll need a test track:

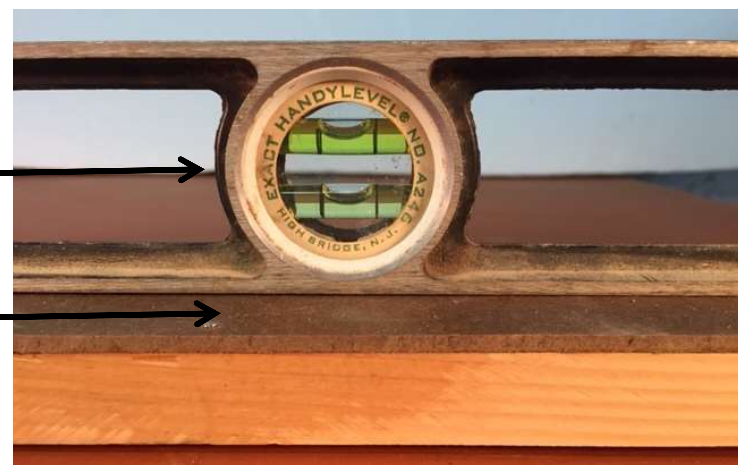
Smooth surfaced dense particle board



Make sure it is level:

Spirit level

Track surface



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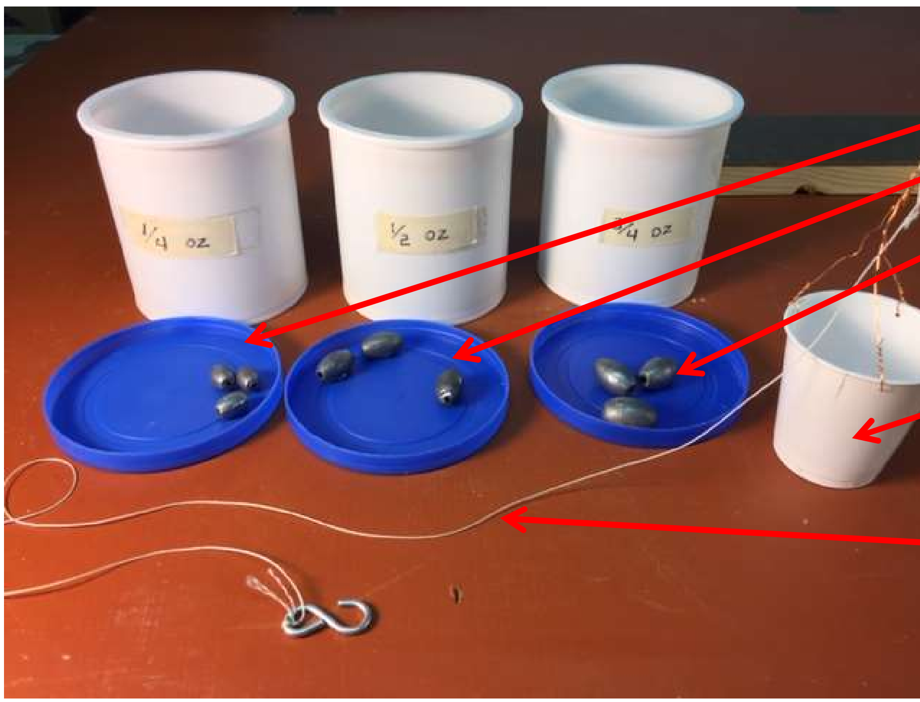
Simple Machines – Wheel and Axle

We'll need some weights:



Lead weights
¼ oz.
½ oz.
¾ oz.

Cup to hold weights

Thread to connect cup with weights to the blocks

A light plastic cup and thin thread are used so their weight will be negligible compared to the weight of the blocks and the lead weights.

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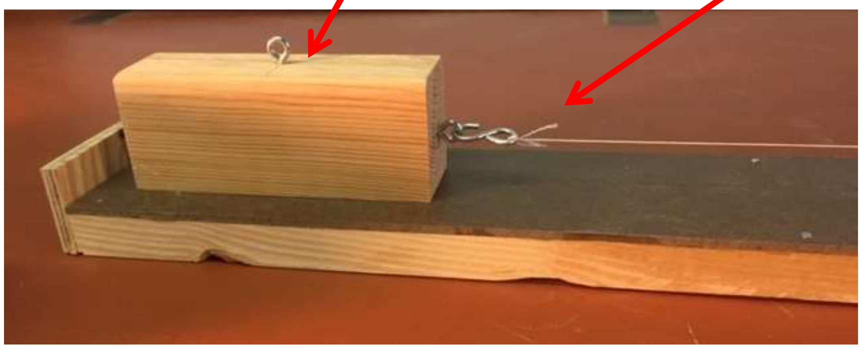
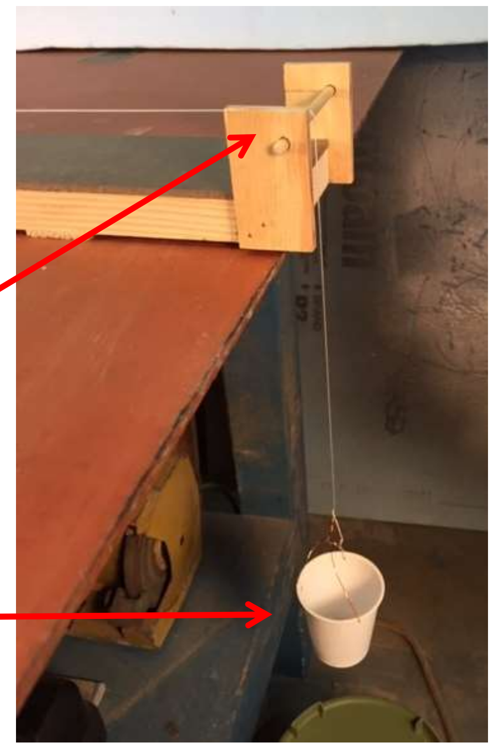
Simple Machines – Wheel and Axle

The test set up:

Set block on track

Attach thread to block





Run thread over a dowel at the end of the track

Suspend cup for weights over the edge of the table

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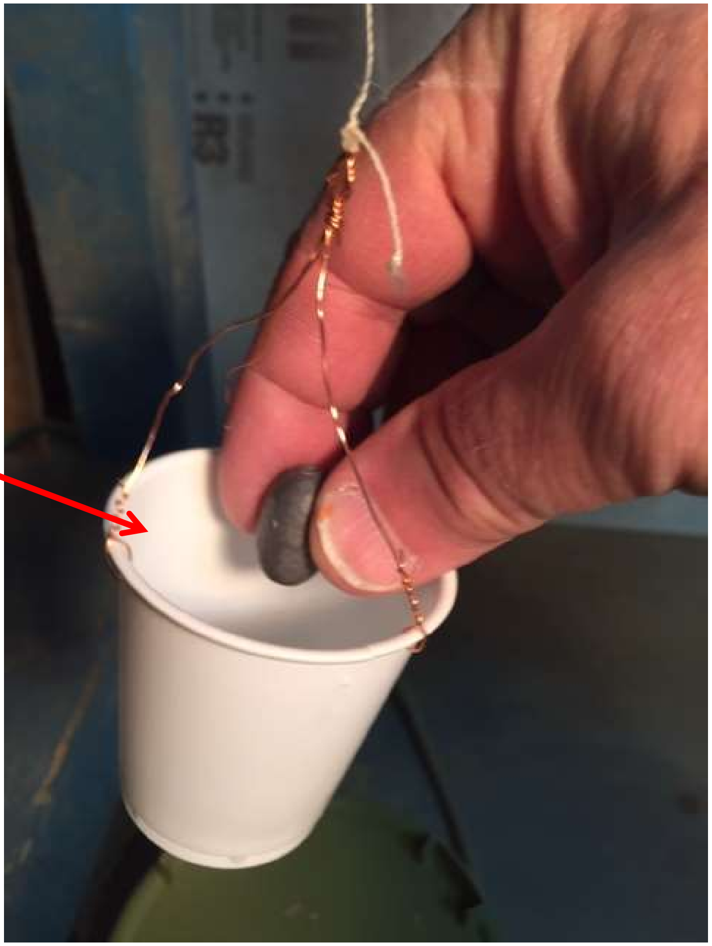
Simple Machines – Wheel and Axle

The test:

Place weights in the cup until the block begins to move. Place the weights in the cup gently and support the cup while placing the weight.



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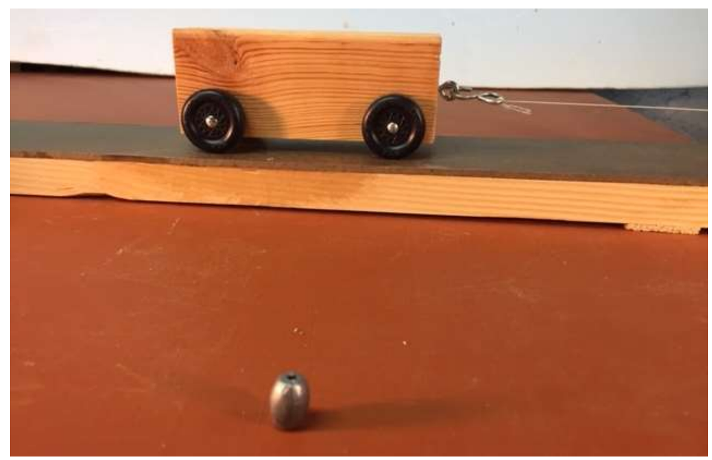
Simple Machines – Wheel and Axle

Test results:

No wheels
3 weights of ¾ oz. and
1 weight of ½ oz. ,
total of 2 ¾ oz. required
to move the block

With wheels
1 weight of ¼ oz.
required to move the
block



10 times more weight required to move block without wheels

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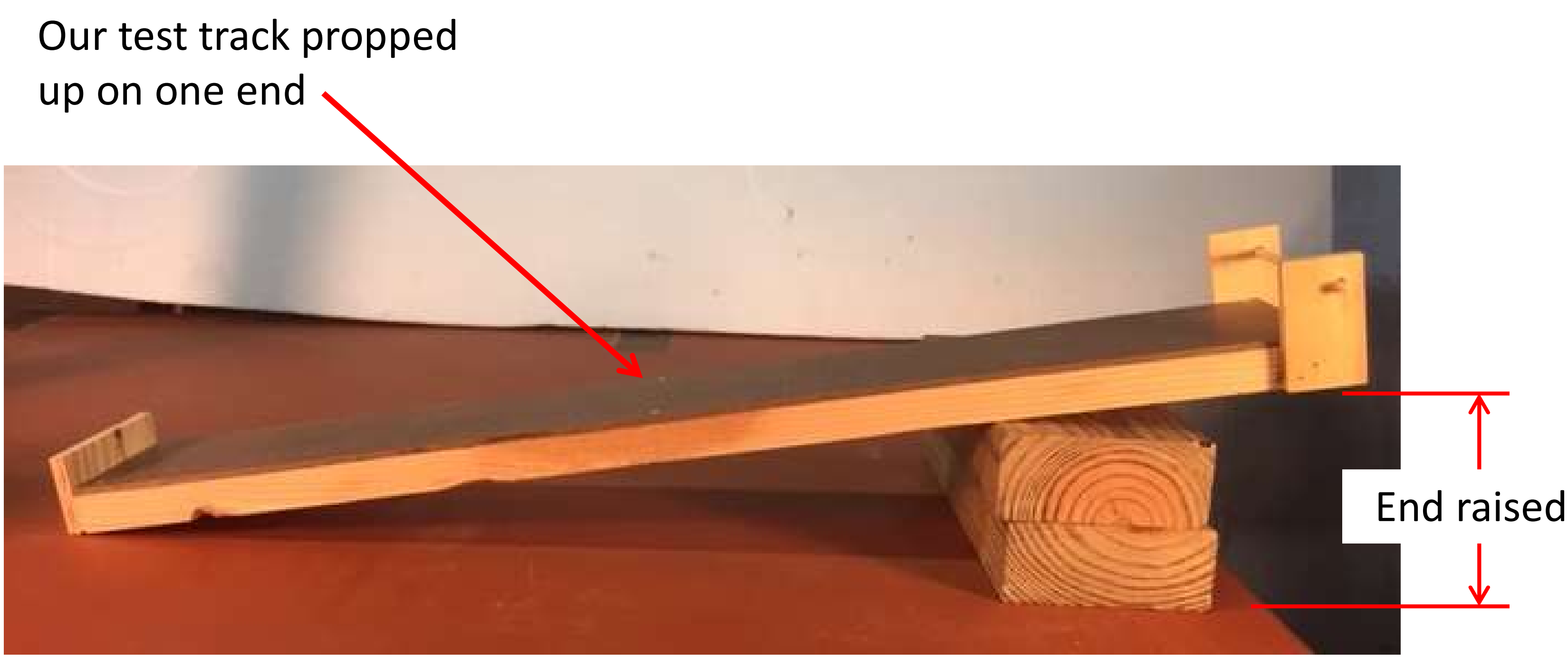
Simple Machines – Inclined Plane

An inclined plane is a sloped surface that enables us to use less force to do an amount of work



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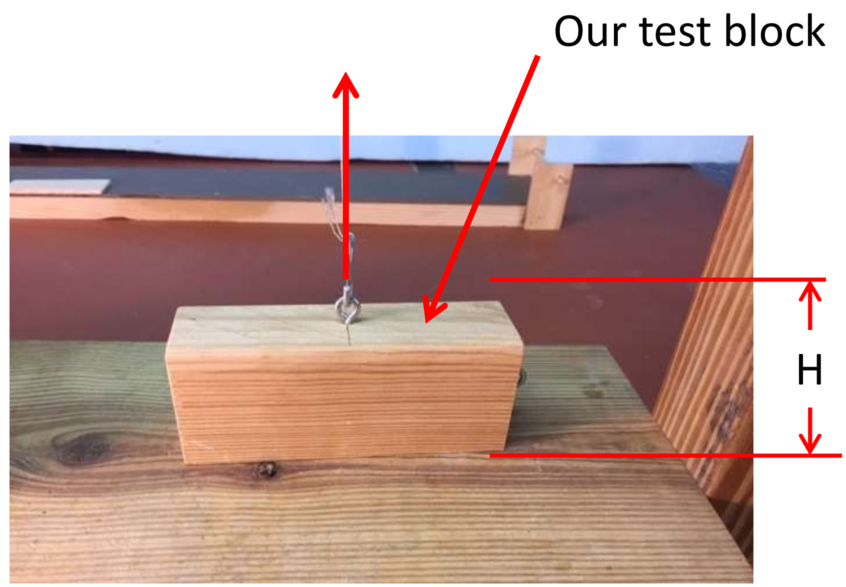
Simple Machines – Inclined Plane

To understand the inclined plane we need to understand work

In physics and engineering "work" is defined as moving a mass a distance. The effort to move the mass is called "force".

Mathematically WORK = FORCE X DISTANCE

As an example, raising the block we used in our Wheel and Axle experiment a height "H" would be WORK



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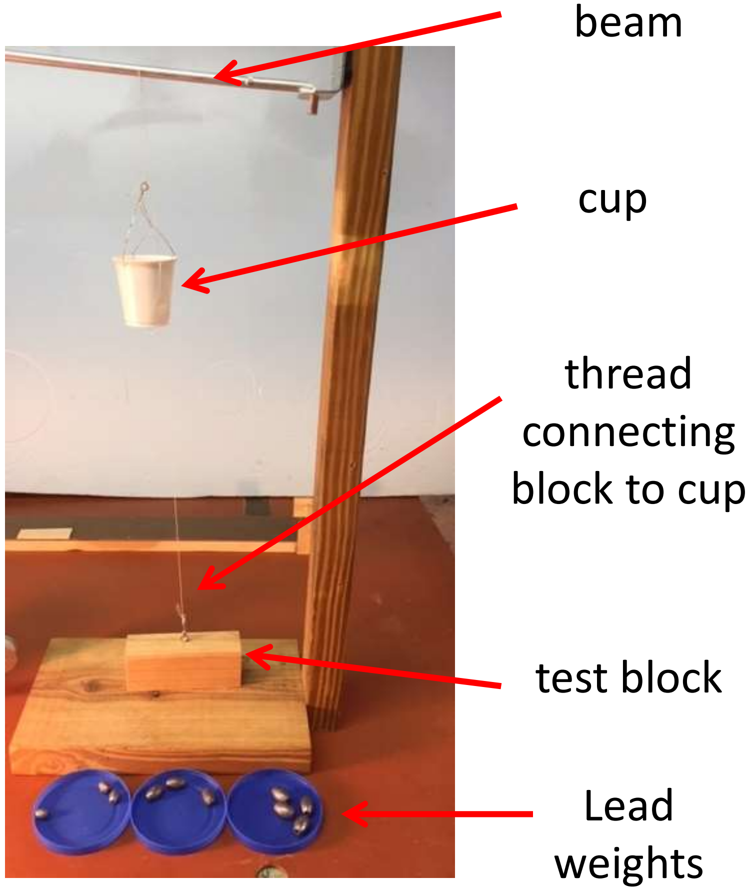
Simple Machines – Inclined Plane

To see how an inclined plane can help let's do an experiment

- ✓ Attach a cup to hold weights to a block with a thread
- ✓ Loop the thread over a beam above the block
- ✓ Place weights in the cup until the block is lifted up



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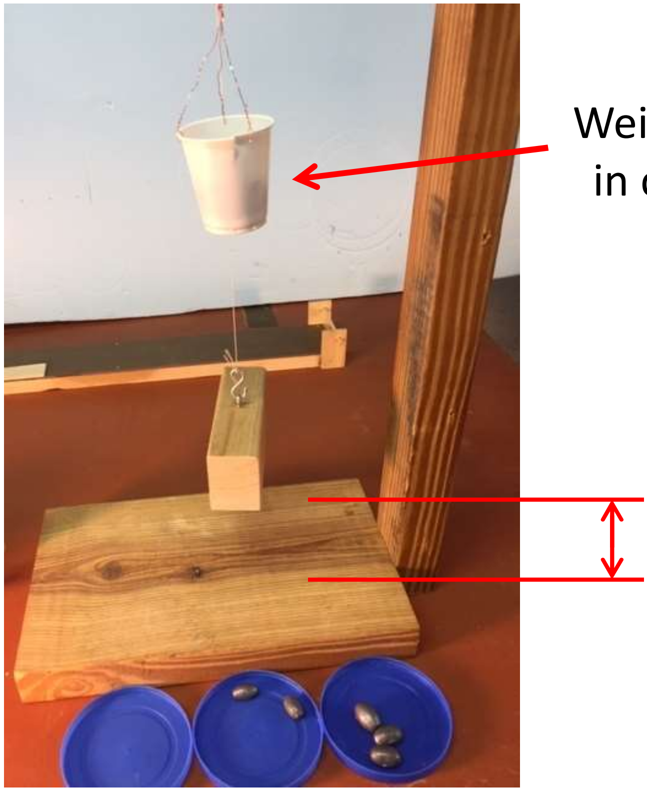
Simple Machines – Inclined Plane

To see how an inclined plane can help let's do an experiment

- ✓ Attach a cup to hold weights to a block with a thread
- ✓ Loop the thread over a beam above the block
- ✓ Place weights in the cup until the block is lifted up
- ✓ When weight in the cup equals the weight of the block the block is raised



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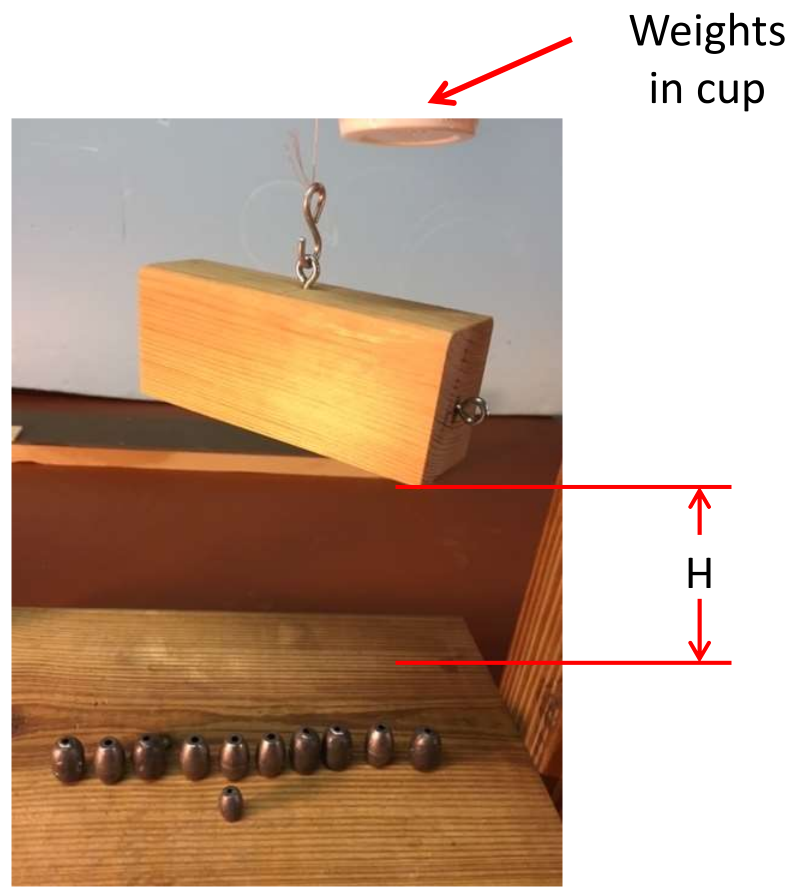
Simple Machines – Inclined Plane

To see how an inclined plane can help let's do an experiment

- ✓ Attach a cup to hold weights to a block with a thread
- ✓ Loop the thread over a beam above the block
- ✓ Place weights in the cup until the block is lifted up
- ✓ When weight in the cup equals the weight of the block the block is raised
- ✓ 10 weights of ¾ oz. and 1 weight of ¼ oz. are needed to raise the block



It took 7 ¾ oz. of weight (FORCE) to raise the block height H

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Simple Machines – Inclined Plane

To see how an inclined plane can help let's do an experiment

Now that we have seen how much FORCE it takes to raise the block straight up, let's see how much FORCE is needed using an inclined plane to raise the block

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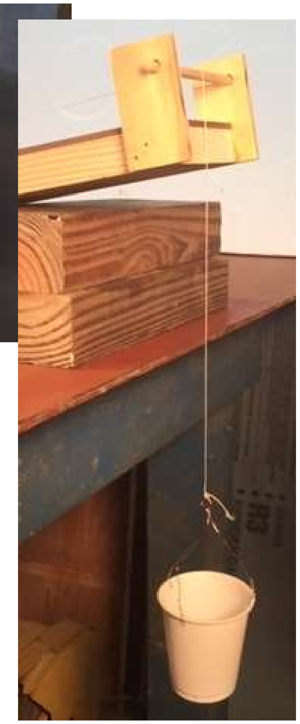
Simple Machines – Inclined Plane

To see how an inclined plane can help, let's do an experiment

test block

thread connecting block to cup



cup

- ✓ Attach a cup to hold weights to a block with a thread
- ✓ Loop the thread over the end of the test ramp
- ✓ Place weights in the cup until the block is lifted up

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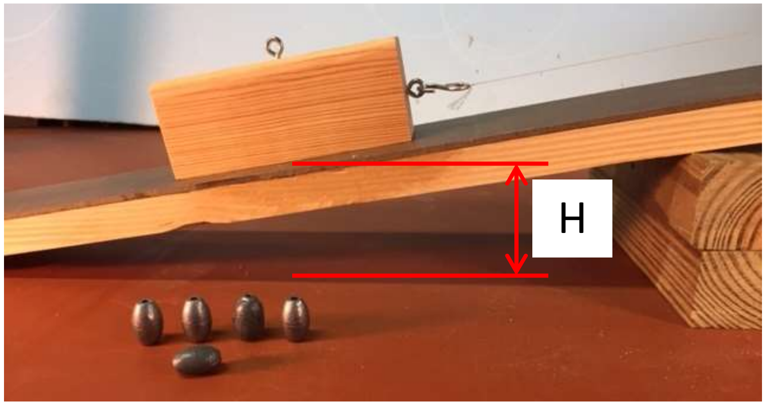
Simple Machines – Inclined Plane

To see how an inclined plane can help, let's do an experiment

- ✓ Attach a cup to hold weights to a block with a thread
- ✓ Loop the thread over the end of the test ramp
- ✓ Place weights in the cup until the block is lifted up
- ✓ When weight in the cup equals the weight of the block the block is raised
- ✓ 4 weights of ¾ oz. and 1 weight of ½ oz. are needed to raise the block



It took 3 ½ oz. of weight (FORCE) to raise the block height H using the inclined plane. It required less than ½ as much FORCE to raise the block to height H using the inclined plane compared to lifting it straight up.

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Simple Machines – Pulley

A pulley is a wheel and axle with a rope or cable run over it. By using a series of pulleys the Force required to lift a mass is reduced

Let's see how a pulley system can reduce the force required to lift a TON OF BRICKS!

Well, a 1/800 scale ton of bricks☺

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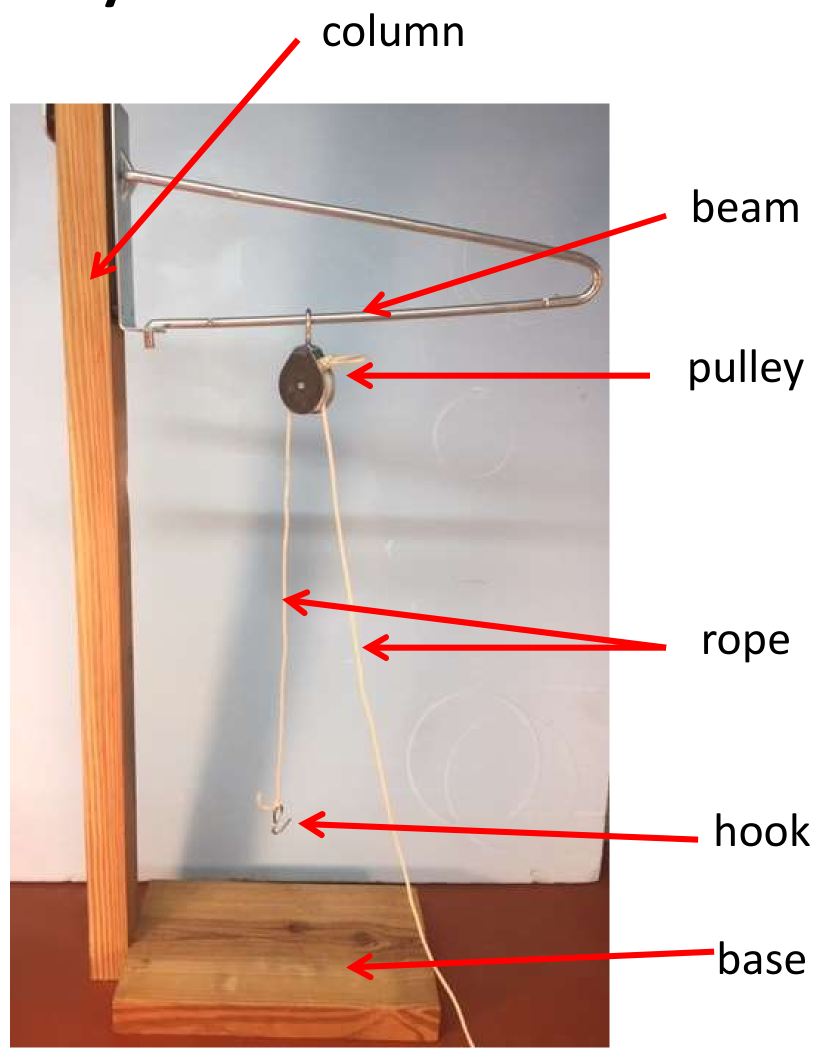
Simple Machines – Pulley

Here is our test rig:

- A vertical column supporting a beam
- A pulley hung from the beam
- A rope run over the pulley
- A hook at the end of the rope to attach the bricks
- A digital fish scale to measure the force

Digital fish scale



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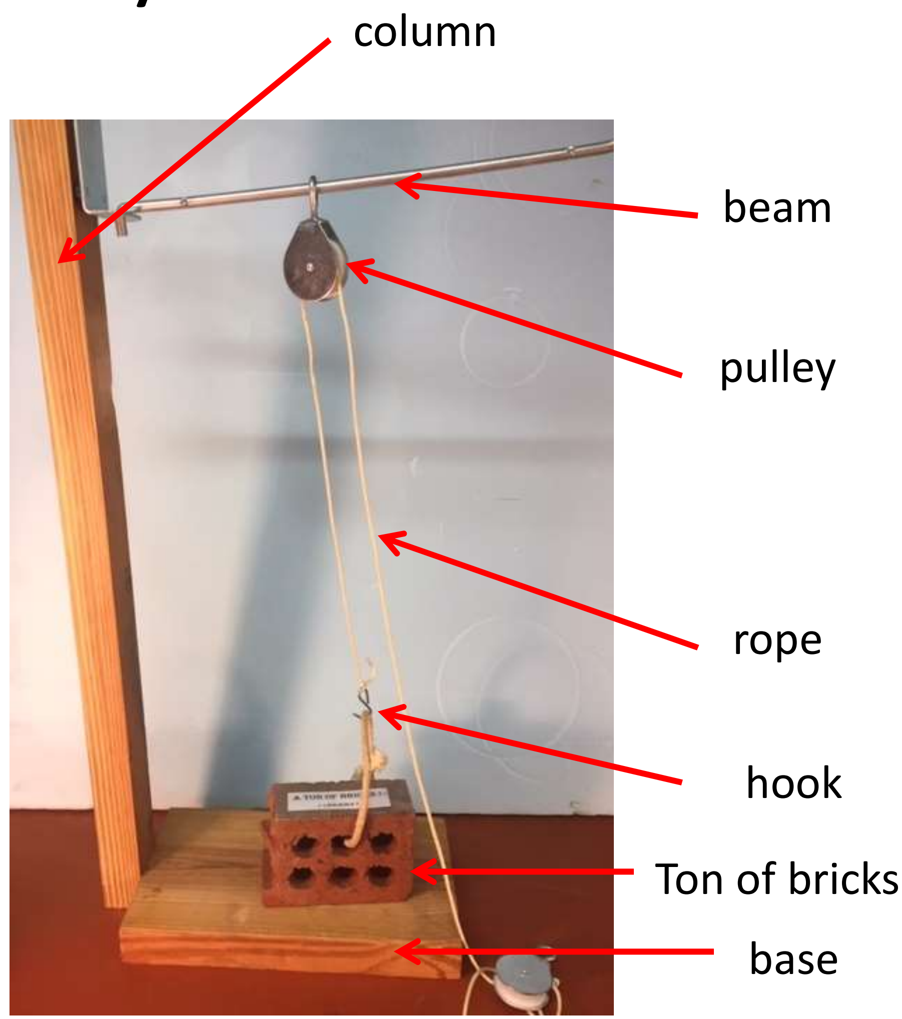
Simple Machines – Pulley

First test using a single pulley



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Simple Machines – Pulley

First test using a single pulley

- Force to lift brick 40.5 oz
- Equal to weight of brick

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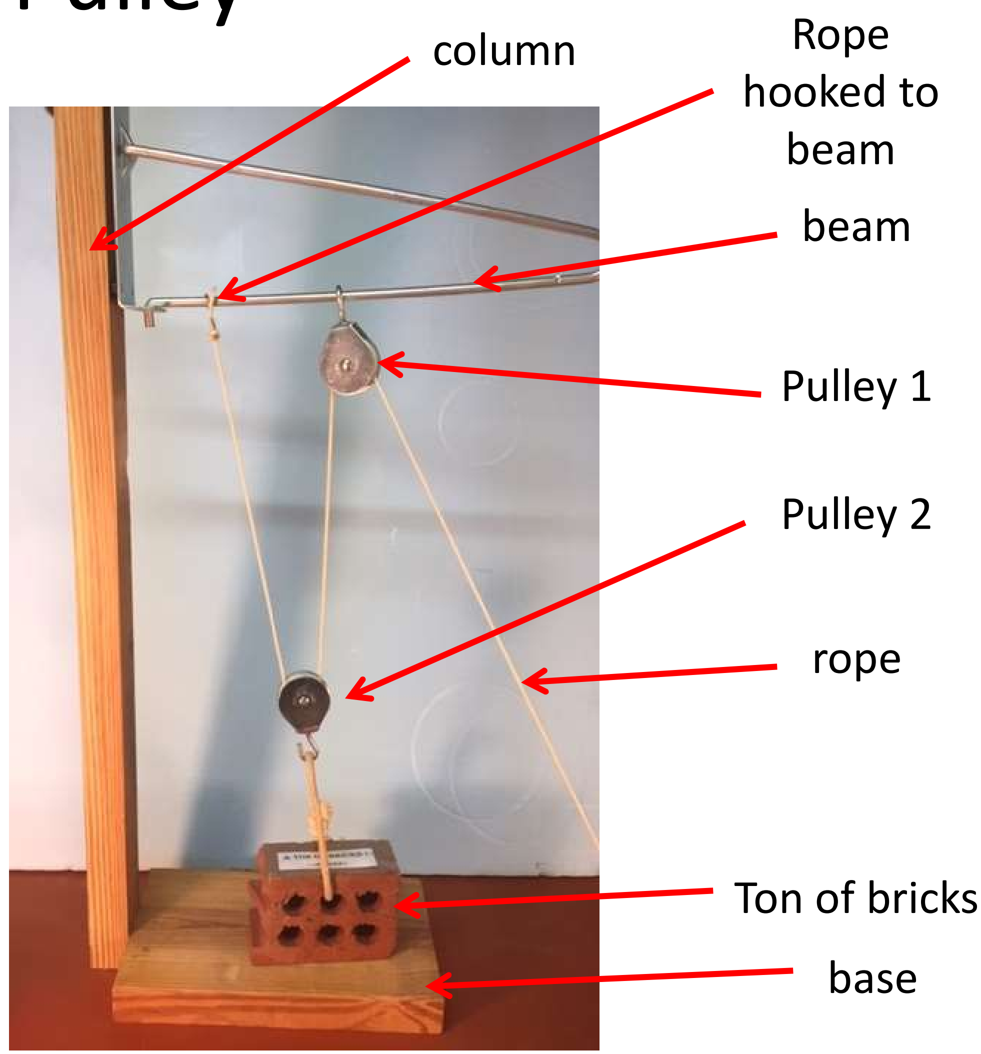
Simple Machines – Pulley

Second test using two pulleys



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Simple Machines – Pulley

Second test using two pulleys

- Force to lift brick 21.5 oz
- About ½ the weight of brick

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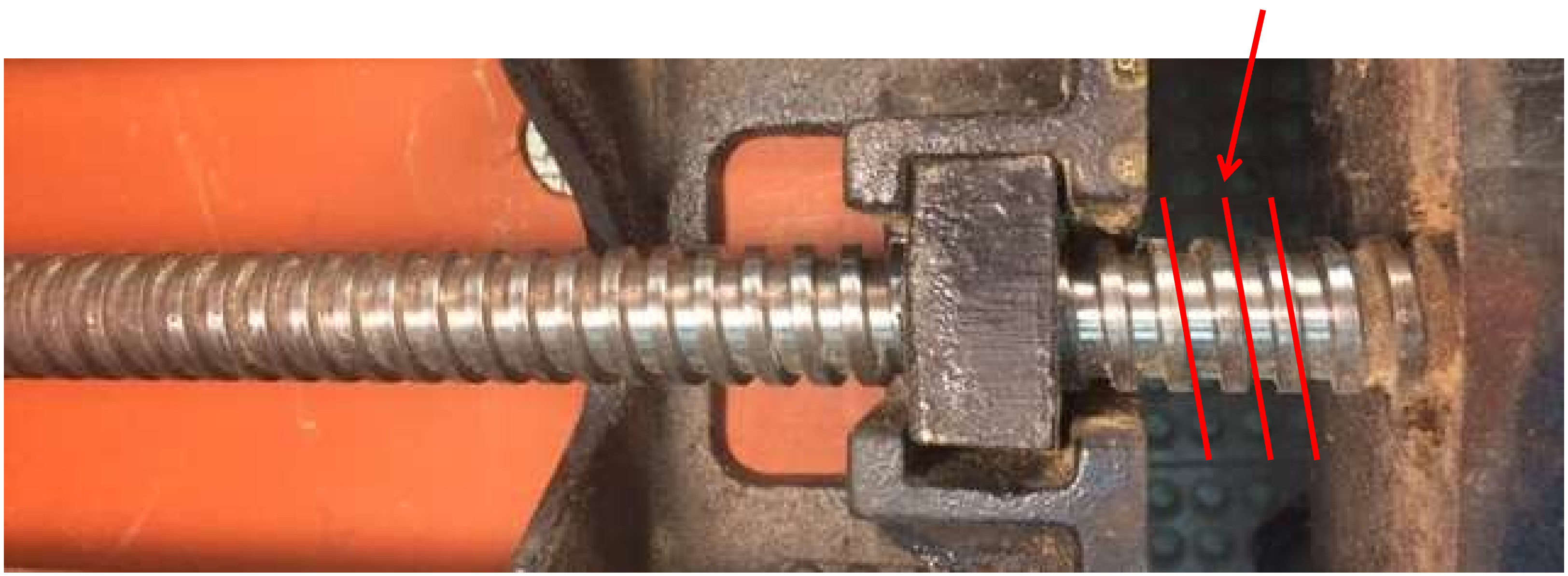
Simple Machines – Screw

A screw is an inclined plane wrapped around a cylinder or cone

- A screw operates by turning



A large screw used in a woodworking bench vise

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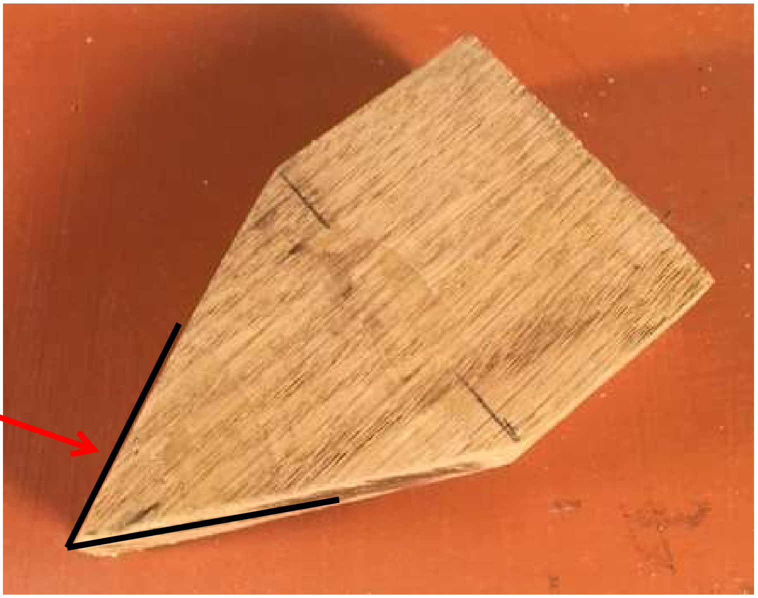
Simple Machines – Wedge

A wedge is a triangular shape

- A wedge operates by being forced between objects to move or separate them

Sharp angle between faces of a wedge



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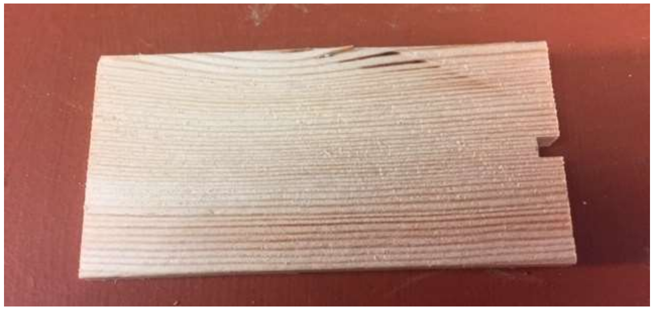
Simple Machines – Screw and Wedge

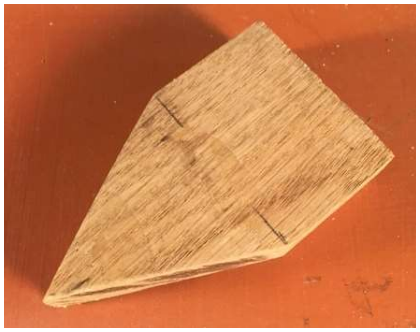
We will illustrate the use of the screw and the wedge together with a model of a log splitter

frame

screw



“log”



wedge

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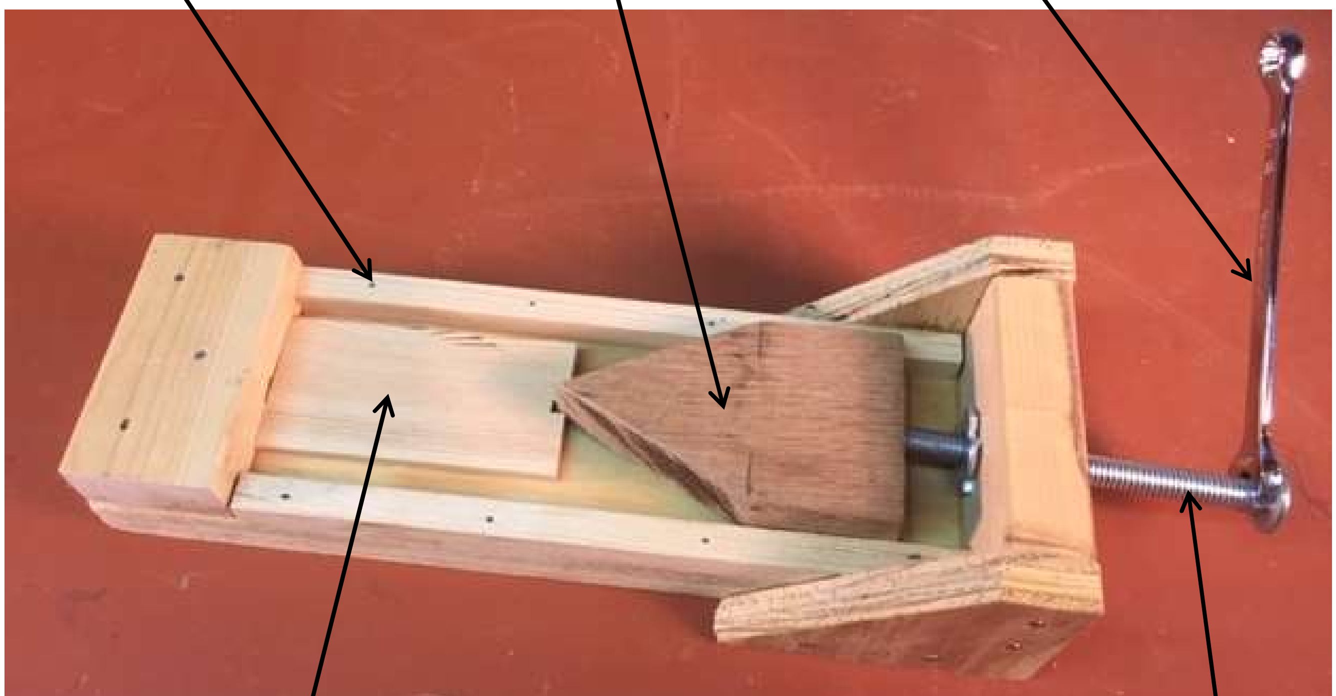
Simple Machines – Screw and Wedge

The assembled log splitter model

Wrench
(What simple machine is the wrench?)

frame

wedge



“log”

screw

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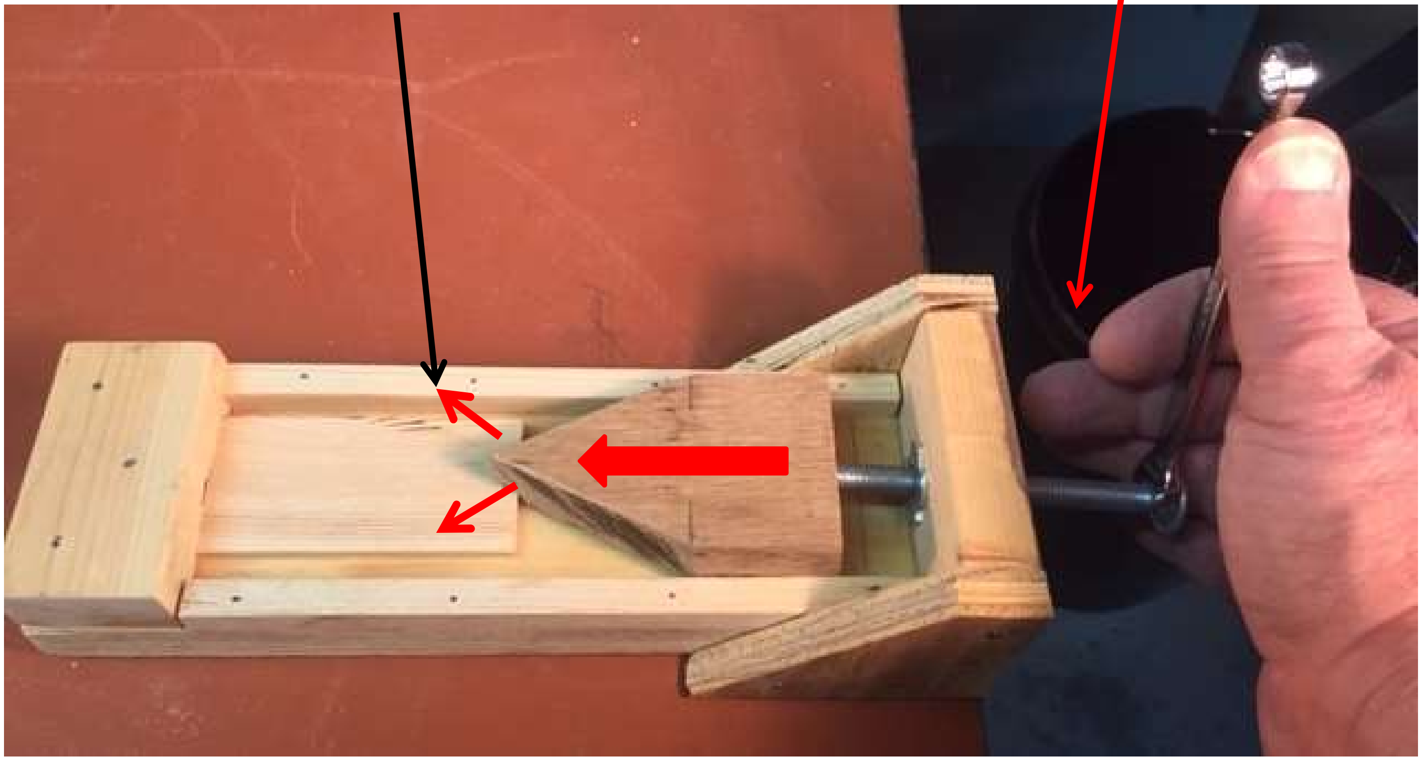
Simple Machines – Screw and Wedge

Operating the log splitter model

Wedge applies outward force on the wood as it is driven forward

Turn the screw to drive the wedge forward into the log



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Simple Machines – Screw and Wedge

Operating the log splitter model