Trust | Deliver | Learn

SIMPLE MACHINES
WHEEL & AXLE

CAT NO. WDMS19

Experiment Guide

GENERAL BACKGROUND :

There are six simple machines that all other machines are made out of. Even complex machines like an automobile really consist of simple machines that all convert energy in order to do work. Machines are used to make work easier. Here work is defined as a force applied over a given distance. The force applied and the distance traveled must be in the same direction.

Simple machines can either change the direction the force is applied, or increase the mechanical advantage by doing the same amount of work over a longer distance and therefore decreasing the amount of force needed.

Mechanical advantage is a way of measuring how much easier it is to do work or how much less force is required. Written as a formula:

$$\text{Mechanical Advantage} = \frac{\text{Output force (load)}}{\text{Input force (effort)}}$$

The load is the amount of force or weight that is being lifted.
The effort is the amount of force or weight being applied to the rope in order to move the load.

The six simple machines are pulleys, levers, wedges, inclined planes, screws and wheels & axles. Compound machines have two or more simple machines that when used together make work easier.

A pulley is a variation of a wheel and axle in which a rope or cord is stretched over a wheel to make it rotate as the rope is pulled. Pulleys are used to raise and lower flags, on oil derricks, to raise, lower, and adjust sails on a sailboat, and to pull open or close curtains. A single pulley can change the direction that a force is needed to be applied in order to make doing work more convenient. A combination of several pulleys can make it easier to do work. By applying a smaller force over a larger distance mechanical advantage is gained.

Levers are in use when a long stiff object, like a post or board rests on a fulcrum. The fulcrum is simply the pivot point on which the board or post rests. The pivot point does not undergo any translational motion (it doesn't move). The lever lifts a load by applying an effort force. The arrangement of the effort, load, and fulcrum determines the “class” of levers. There are three classes of levers.

In first class levers as shown in diagram 1:

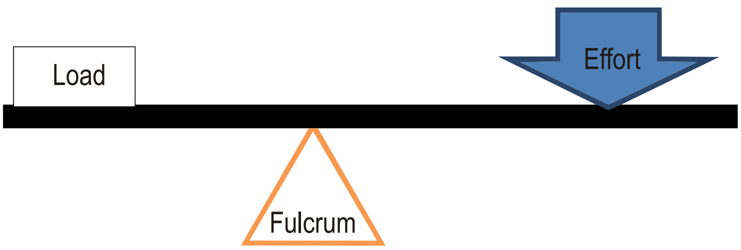

Diagram 1

Examples of class one levers are a teeter totter or see-saw, a catapult, scissors, or a crowbar.

In class two levers as shown in diagram 2:

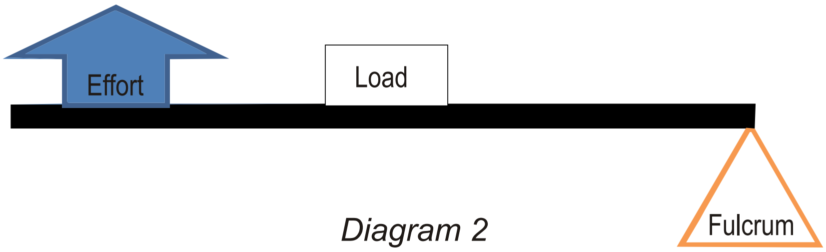

Diagram 2

Class two levers have the load in the middle and the fulcrum on the end and the effort is applied on the opposite side of the fulcrum as shown in diagram 2. Examples of class two levers are wheel barrows, shovels, and nutcrackers.

In class 3 levers as shown in diagram 3:

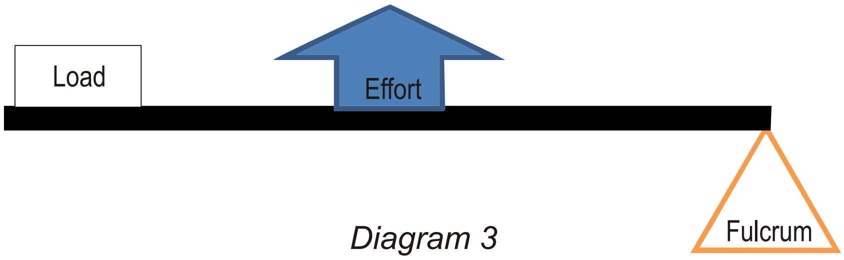

Diagram 3

Class three levers have the load on one end of the post, the fulcrum on the opposite end, and the effort is applied to the middle as shown in diagram 3. A fishing pole, tweezers, or your forearm are good examples of class three levers.

A wedge is a simple machine that changes the direction of a force. The force applied is usually perpendicular to the force acting on the object. Examples of wedges are door stops, nails, axes, teeth (incisors, not molars), pins, and a chisel.

Wheels and axles increase mechanical advantage by covering a longer distance using less force. The larger the wheel the greater the mechanical advantage. When bikes were first invented, many inventors tried to increase the mechanical advantage of the bike by increasing the size of the wheel that was being rotated. The famous Penny Farthing bike increased the distance traveled for each rotation of the pedal by having a very large front wheel. A rider needed to run alongside the bike to get it started before jumping on a board since the pedals were too difficult to push from a stand still. Although this did increase the amount of distance covered by one rotation of the wheel, it also made the bicycle clumsy to ride and pedal.

As a wheel turns the distance traveled by the one rotations of the wheel is directly proportional to the diameter of the wheel. For the penny farthing bike one rotation of the petal equals one rotation of the bike's wheel. However the distance covered by the person's foot is much smaller than the distance covered by the bikes wheel.

Examples of wheels and axles include bike tires, car tires, windmills, and steering wheels. In diagram 4 there is a red string wrapped around two different diameter wheels. As each wheel is pushed forward with the same force it turns one complete rotation and rolls the red string out on the ground. Compare the distance traveled by each wheel.

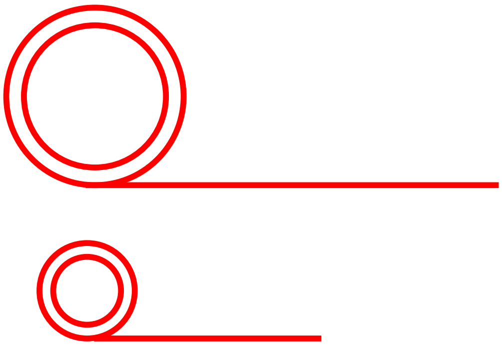

Diagram 4

As you can see the distance traveled by the larger wheel is farther than that of the smaller wheel. The bigger the wheel, the less force is needed to do the same amount of work.

Inclined planes also increase mechanical advantage by increasing the distance traveled and decreasing the amount of force applied. Examples of inclined planes include ramps, hills, ladders, stairs and the backs of dump trucks.

Screws are really just inclined planes wrapped around a post as shown in diagram 5. Examples of common screws are screw top jar lids, drill bits, meat grinders, corkscrews, swivel stools, and of course, screws.

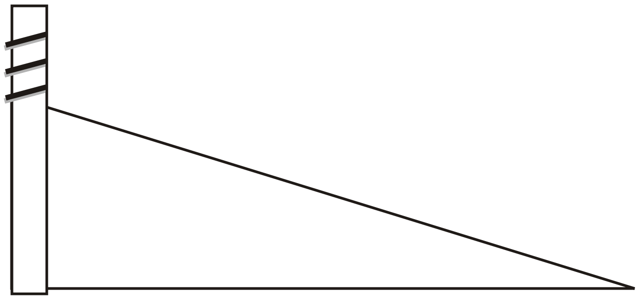

Diagram 5

REQUIRED COMPONENTS (INCLUDED)

Name of Part	***Quantity***
Wheel and Axle Base	1
Two wooden blocks connected by a rope	1

REQUIRED COMPONENTS (NOT INCLUDED)

Name of Part	***Quantity***
Ruler	1

ACTIVITY 1: THE SLIDE (TEACHER ANSWERS)

1. Push your wheel and axle apparatus along a smooth soft surface as shown in diagram 6.

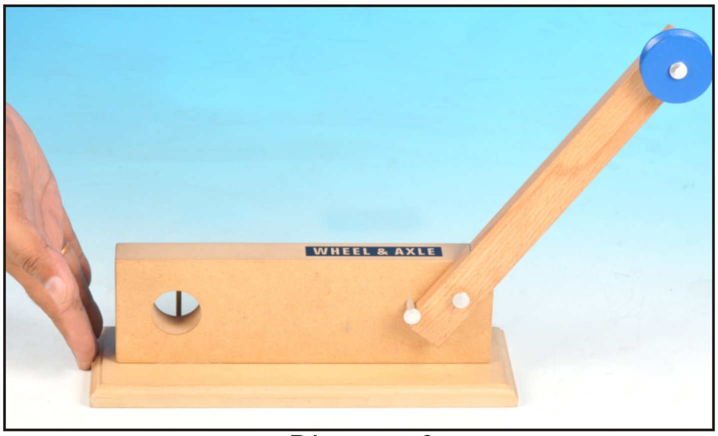

Diagram 6

2. Now turn your wheel and axle apparatus upside down and wheel it across the same surface as shown in diagram 7.

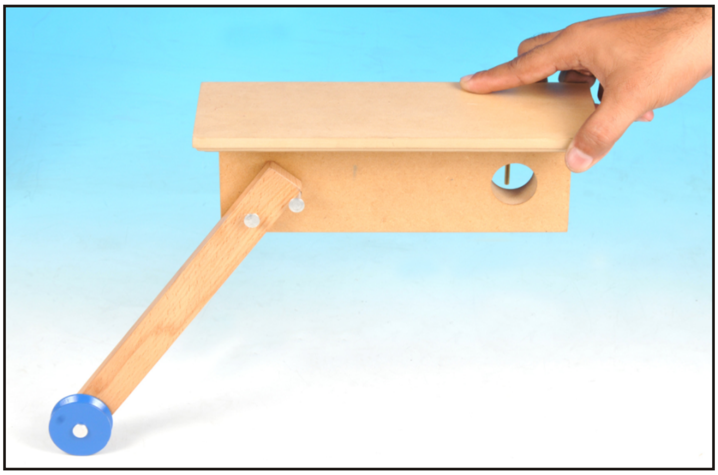

Diagram 7

3. Compare the amount of force it took to wheel your apparatus versus slide your apparatus.

   (It took less force to move the apparatus with the wheel than it did to move it while sliding across the table.)

4. Did the wheel make your work easier, harder, or about the same?

   (The wheel made my work easier because it required less force to move the same distance. Since work is force multiplied by distance, a smaller force means that less work is done.)

NAME:______________________________________ DATE:______________

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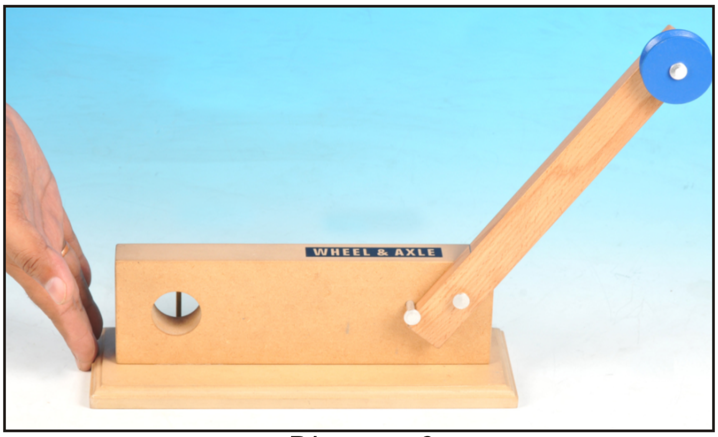

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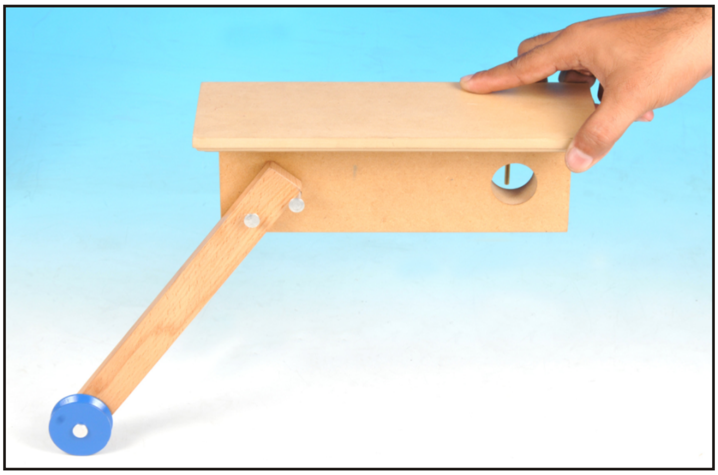

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ACTIVITY 2: THE CRANE (TEACHER ANSWERS)

This apparatus can be used like a pulley and to demonstrate how different types of cranes work.

In diagram 8 both wooden blocks are balanced on the pulley because they have the same mass, which means that gravity is pulling on each block with the same force.

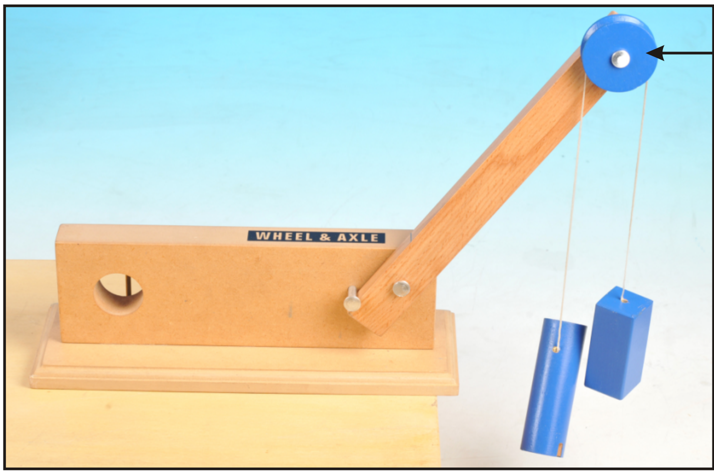

Diagram 8

1. Using this information, what can you say about the mechanical advantage of a single pulley?

   A single pulley has a mechanical advantage of 1, since the effort force and the load force are the same.

$$\textit{Mechanical Advantage} = \frac{\textit{Output force (load)}}{\textit{Input force (effort)}}$$

The wheel and axle apparatus can be set up like a crane as well. A crane is a device used to lift and transport heavy loads, typically in construction sites. A rope attached to a winch allows the load to be raised and lowered. A winch is just rope wrapped around a cylinder that can rotate to bring the rope in or let it out. Some are mechanically driven, and some are driven by a hand crank. The hand crank increases the mechanical advantage by using a lever to apply a greater force to the winch.

2. Can you identify the winch in this crane? Label it in diagram 9.

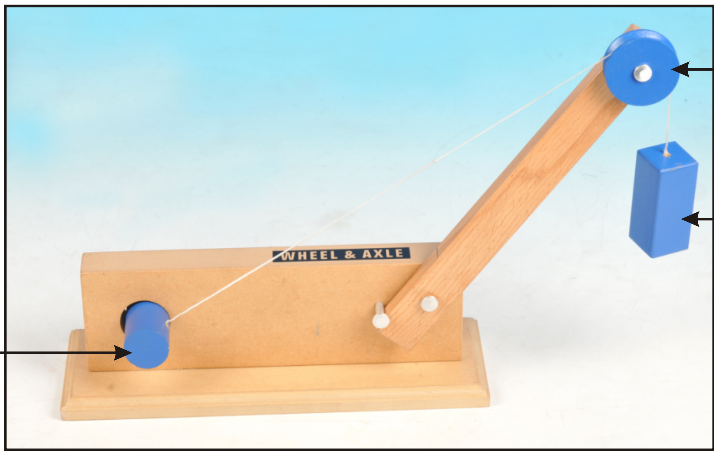

Diagram 9

3. Label the load that the crane is lifting on diagram 9.

4. What is the purpose of the pulley at the top of the crane? Does it increase the mechanical advantage, change the direction of the force applied, or both?
(The pulley changes the direction of the force only. Two or more pulleys are needed to change the mechanical advantage of simple machine.)

5. The boom arm of the crane allows the load to be lifted over ditches, water, ravines and other hazardous areas. Pull the boom arm in towards the crane as shown in diagram 10. Label the load, effort and fulcrum. Show the direction of the load with an arrow.

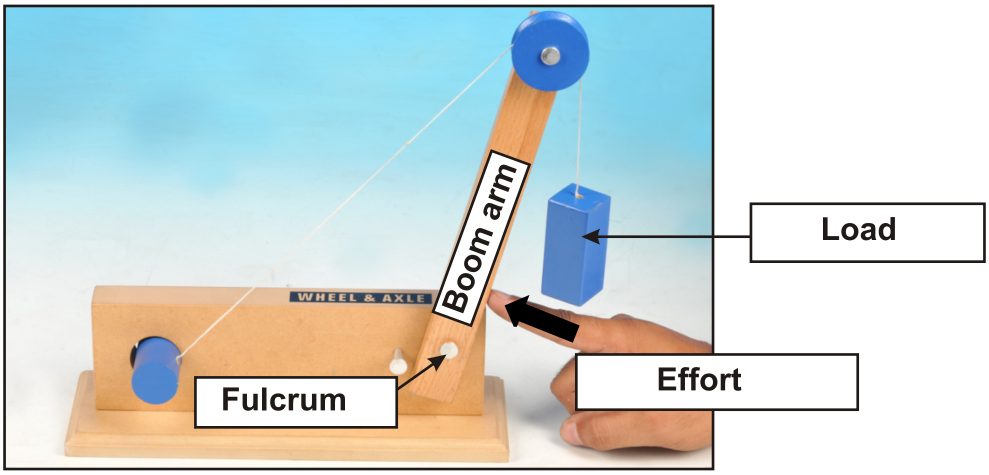

Diagram 10

6. What class lever is the boom arm? *(class 3 lever)*

7. If the load is too heavy on a crane, the crane can tip over. Pull down on the load gently until it begins to tip. Now the crane is acting like a different kind of lever. Label the load, effort and fulcrum in diagram 11.

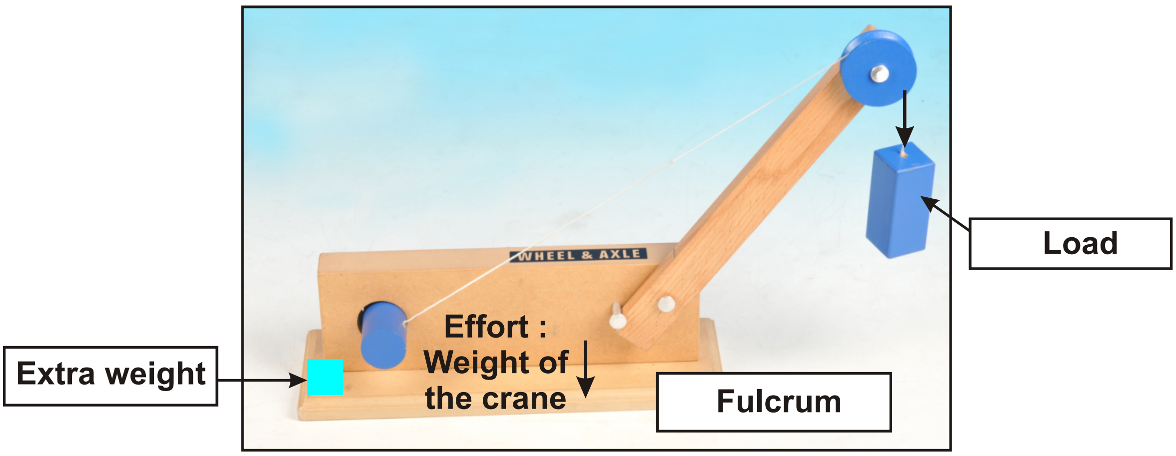

Diagram 11

8. What class lever is the crane acting as in this scenario? *(a first class lever)*

9. If a construction worker knows he is going to lift a very heavy load, then he has to add extra weight to part of his crane. Where would you recommend placing the extra weight? Draw it in diagram 11 and write a few sentences explaining why you would put your weight there.
(I would put the weight next to the winch because adding weight to the opposite side of the fulcrum as the load would allow the load to be heavier. I would move the weight as far from the fulcrum as possible because that would increase my mechanical advantage.)

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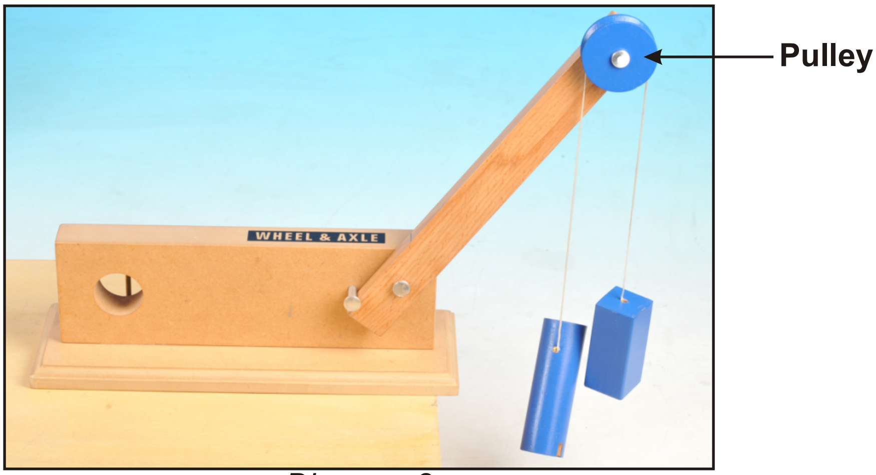

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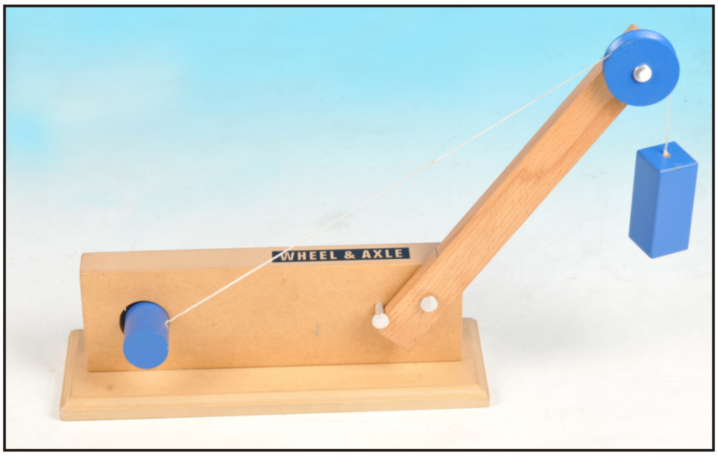

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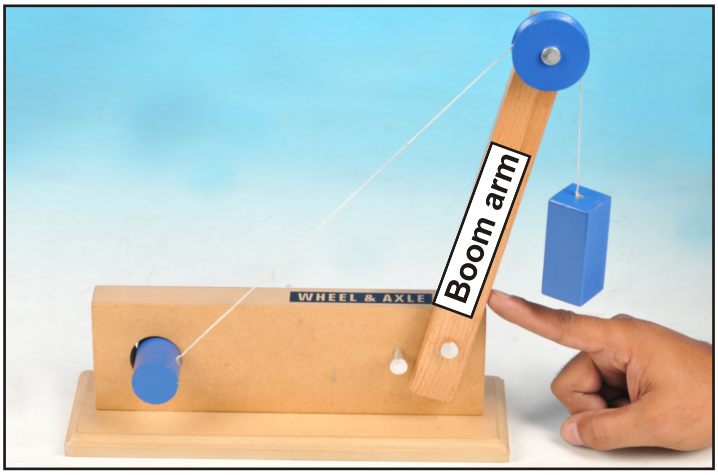

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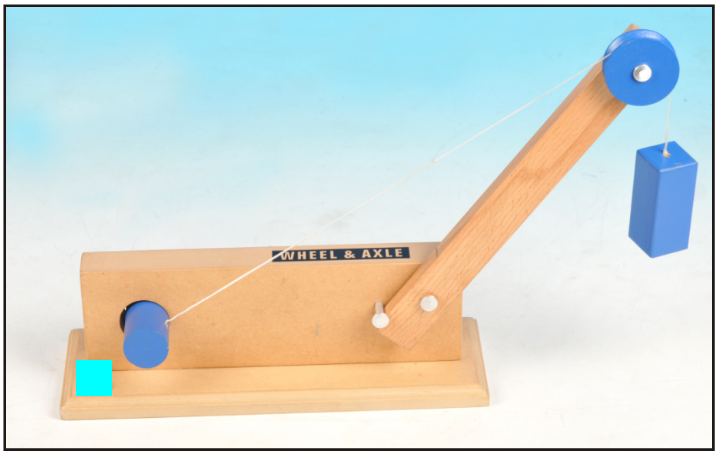

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