Throughout the guide teaching tips are in red.

Activity Description and Estimated Class Time

This 2-day activity introduces students to simple machines and mechanical advantage. Small teams of students rotate among four different simple machine stations: a wheel and axle, an inclined plane, a lever, and pulleys. A weight and a spring scale are at each station, and students are challenged to set up the simple machine to lift the weight using the least amount of force, and to take note of how they arranged the weight, the spring scale, and the machine. After class discussion, teams determine the "force multiplier," or "mechanical advantage," the amount the simple machine multiplies the force. Afterward, students explain how simple machines are used to create mechanical advantage.

Objectives

Students will develop an understanding of the following ideas and content:

- Simple machines are things that you do work on, and they do work on something else,
- Simple machines multiply the force put into them,
- Simple machines trade motion for force: a large motion going in with a small motion coming out allows a small force to exert a large force.

Correlations to North Carolina Science Standards

7.P.2.4 Explain how simple machines such as inclined planes, pulleys, levers, and wheel and axle are used to create mechanical advantage and increase efficiency.

Brief Science Baground

Simple machines increase the force you apply to something. You apply force to the machine, and it applies force to something else. In the process, the machine turns smaller forces into larger ones. The part that moves farther uses less force and the part that moves less applies more force. Apply a small force to a simple machine over a long distance, and the machine applies more force to something else, but over a shorter distance. For example, push a lever a long way down with a little force, and the other end of the lever applies a lot of force to a heavy object. However, it lifts the object only a short distance. The ratio of force in to force out of a machine is its "force multiplier," or its "mechanical advantage." If a pulley lifts 10 pounds using 5 pounds of force, its force multiplier is 2.

Materials and Procedures

Part 1 – Simple machines exploration (50 minutes)

Materials for each student

- Support Document 2 (double sided sheet)

Materials for stations (2 of each)

- Inclined plane stations, at each:
  - Inclined Plane Station Directions
  - Nut in a bag with safety pin (nut, 4 x 6 zip bag, safety pin)
  - A spring scale
  - A wooden ramp
  - 4 books*
  - A wooden car
- Wheel and axle stations, at each:
  - Wheel and Axle Station Directions
  - Nut in a bag with safety pin (nut, 4 x 6 zip bag, safety pin)
  - Spring scale
  - Plastic wheel
  - 2 pieces of string, one 40 cm long, one 70 cm long
  - 1 dowel, 1/4" by 8 inches
  - Small plastic tube (pen housing)
  - Masking tape
- Lever stations, at each:
  - Lever Station Directions
  - Nut in a bag with safety pin (nut, 4 x 6 zip bag, safety pin)
  - Spring scale
  - Wooden ramp
  - Ruler
  - Prism-shaped wooden fulcrum
- Pulley stations, at each:
  - Pulley station directions
  - Nut in a bag with safety pin (nut, 4 x 6 zip bag, safety pin)
  - 1 spring scale
  - 2 pulleys
  - 1 piece of string about 1 meter long
  - 1 ruler with a small hole in one end
  - 2-3 books to weight the rulers*

* supplied by the teacher

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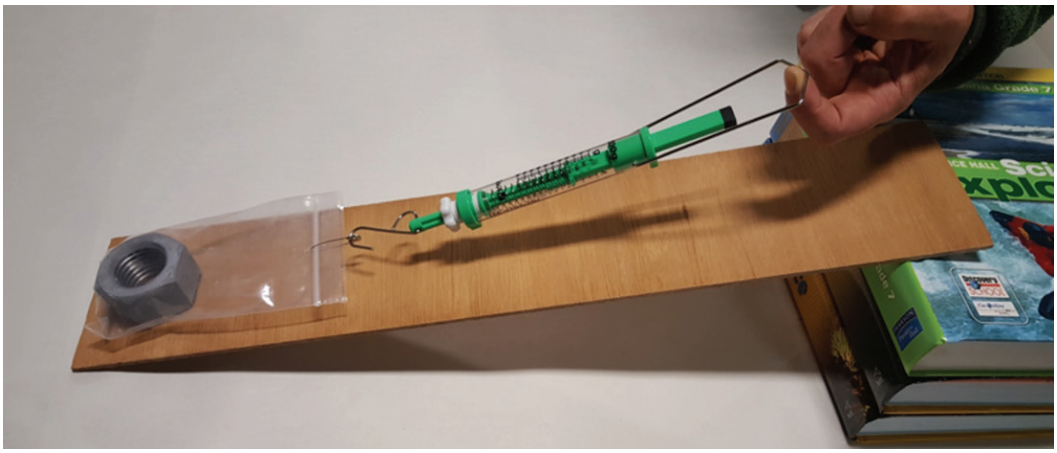
Preparation

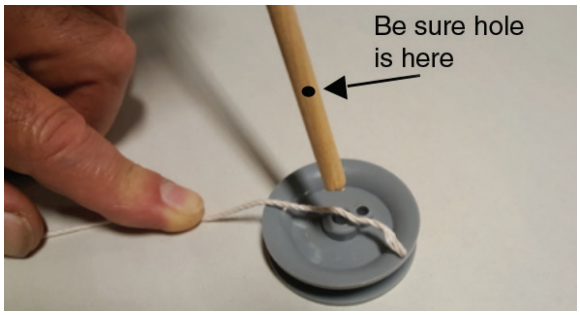
1. Make 2 copies each of all 4 pages of Support Document 1. Set up two each of the four stations (8 stations in all), each with its copy of Support Document 1.
2. Make double-sided copies of Support Document 2, one per student. Side 1 and Side 2 of Support Document 2 should be on the same sheet of paper.
3. Calibrate the spring scales (adjust to read zero when scale is vertical with hook hanging down).
4. Place large nuts in 4 x 6 zip bags. Attach a safety pin to the bag opening (see illustrations for stations).
5. Cut one 40cm and one 70cm string for each wheel and axle station.

1. Inclined Plane Stations



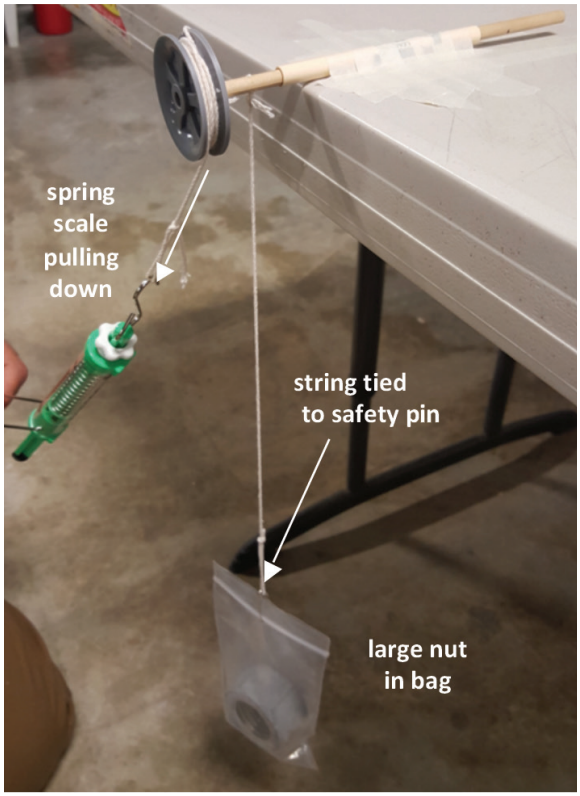
2. Wheel and Axle Stations

First, put the 70 cm strings on the wheel by pushing string into the wheel hole with the axle. This holds the string for winding in the groove on the outside of the wheel.



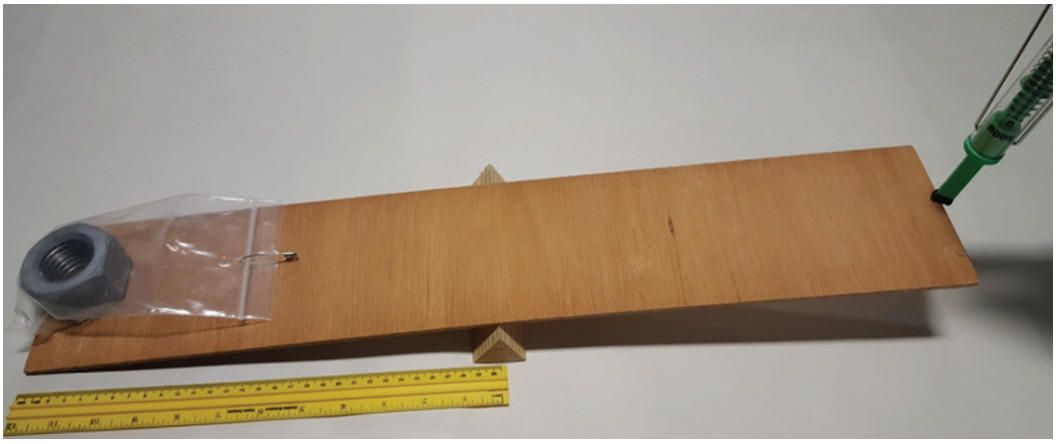
The 40 cm string goes through a hole in the axle and hangs straight down through the dowel without being wrapped around it. This allows the string to wrap either way around the dowel, so that it does not matter which way students wrap string around the wheel. Tape the tube firmly (half a dozen pieces of tape) to overhang the table by half an inch. Slide the axle into the tube leaving the string through the dowel free.

Hang the large nut from the safety pin through a loop in the string that hangs from the dowel, so that the weight is just off the floor. To read the force needed, students will pull down on a spring scale attached to the string wrapped around the wheel.



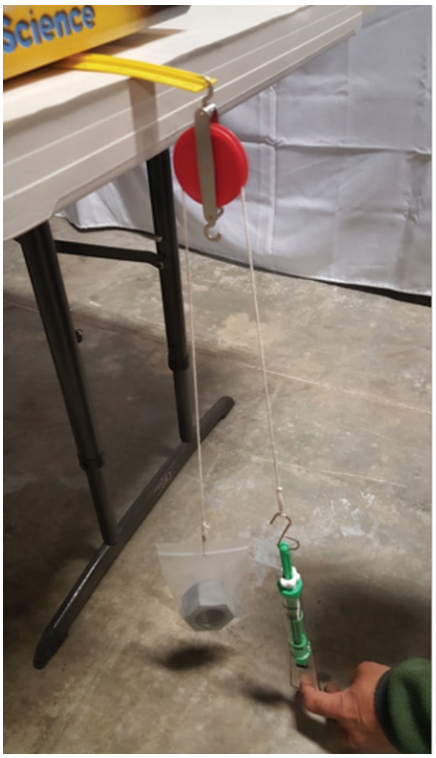
3. Lever Stations

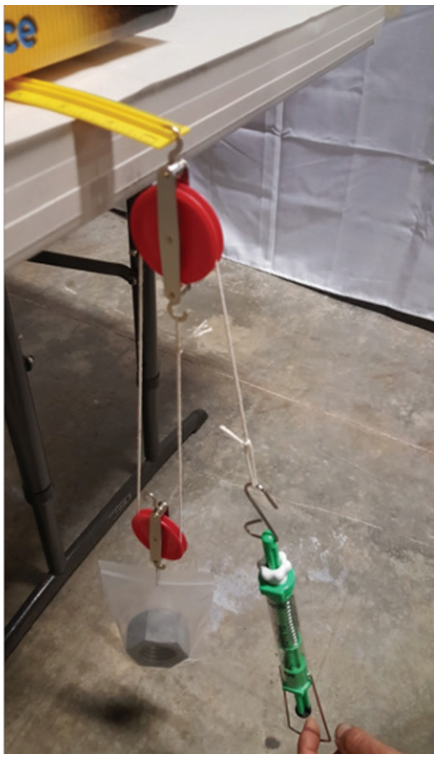
Push the spring scale down on the lever to measure force.



4. Pulley Stations

At pulley stations, students find the single pulley shown on the left below. It hangs from a ruler with a hole in it, extending out from the table as shown. The string over the pulley is tied to the weight and the spring scale. Another pulley is on the table. After using the single pulley, students add the other pulley to make a double pulley shown at the right below. In this setup, the weight is hooked to the lower pulley. The string is hooked to the upper pulley and goes through both pulleys.





Exploration

1. Project Exploration Support Document and ask students to share what these things have in common. Accept all answers. The goal is for students to see that these things make work easier. Inform students that these items are all simple machines. This activity will explore how simple machines make work easier.

Procedure

1. Form 8 teams of 3-4 students and give each student a copy of Support Document 2 (Student Sheet). Around the room are four different kinds of simple machines, 2 stations of each. Every team must go to all four. Their challenge at each station is to find a way to use the machine so that it requires the least amount of force to lift the weight and to fill out Support Document 2.
2. Project Support Document 2 and guide the class about filling it in. As teams rotate through the stations, they will follow directions at each station.
3. When everyone understands what to do, send teams to the stations. After 5-10 minutes, ask them to go to a station with a different machine. Repeat until everyone has visited all four simple machines.
4. Ask everyone to return to their seats and, in their notebooks, explain how to make each machine use the least force to lift the weight.
5. Hold a class discussion about what students wrote for each machine.

Tip: leave one of each station in place to use in part 2.

Part 2 – Mechanical Advantage Hunt

Materials for the each student

- Support Document 2 filled out from previous day

Materials for groups of 2 students

- Inclined plane
- Wheel and axle
- Lever
- Pulley

Preparation

1. Prepare to have one each of the 4 types of stations ready for demonstration.

Procedure

1. Review the discussion from the previous class about students' conclusions about how to make each machine use the least force. Ask for evidence supporting these directions using Support Document 2 to show the amounts of force needed with different setups of the machine (e.g. fulcrum closer or farther from weight, single pulley v. double pulley, lower inclined plane v. higher one, etc.) Get multiple teams to compare results with the same machine.
2. Explain that simple machines can turn a small force into a bigger one. The amount that they do that is called mechanical advantage. Mechanical advantage

is the amount that a machine increases the force. The exact amount that the force is increased is the "force multiplier." Calculate the force multiplier by dividing the force to lift a weight without a machine by the least amount of force needed to lift the weight with a machine.

3. Ask each team to calculate the force multiplier for each machine based on the information they have on Support Document 2. When the class has done this, share the force multipliers for each machine. Which one has the most mechanical advantage?

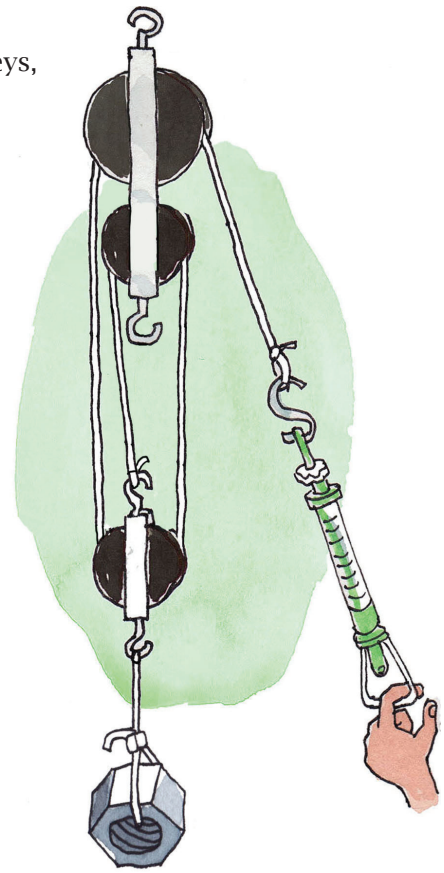
Answer Key

- **The levers have the most mechanical advantage, depending on how they are set up.**
- **The double pulley's force multiplier is about 2.**
- **The inclined plane's force multiplier can be from 2 to 4.**
- **The lever's force multiplier may be very large (almost no force needed to lift the weight)**
- **The wheel and axle force multiplier will be about 5.**

4. Hold a class discussion about what students have discovered. Try to get their ideas about these machines. **As needed, use the stations that are still set up to demonstrate student ideas.**

5. At the Wheel and Axle station, we measured the distance the force was applied and the distance we lifted the weight. Ask students what they noticed about this. **You had to pull the string much farther than the weight moved. While simple machines increase the force applied, they also increase the distance over which the force must be applied.** Tell the class that in the next activity, Levers Around the House, we will go into this in greater depth.

6. Ask the class to write, in their notebooks, how simple machines such as inclined planes, pulleys, levers, and wheel and axle are used to create mechanical advantage and increase efficiency.

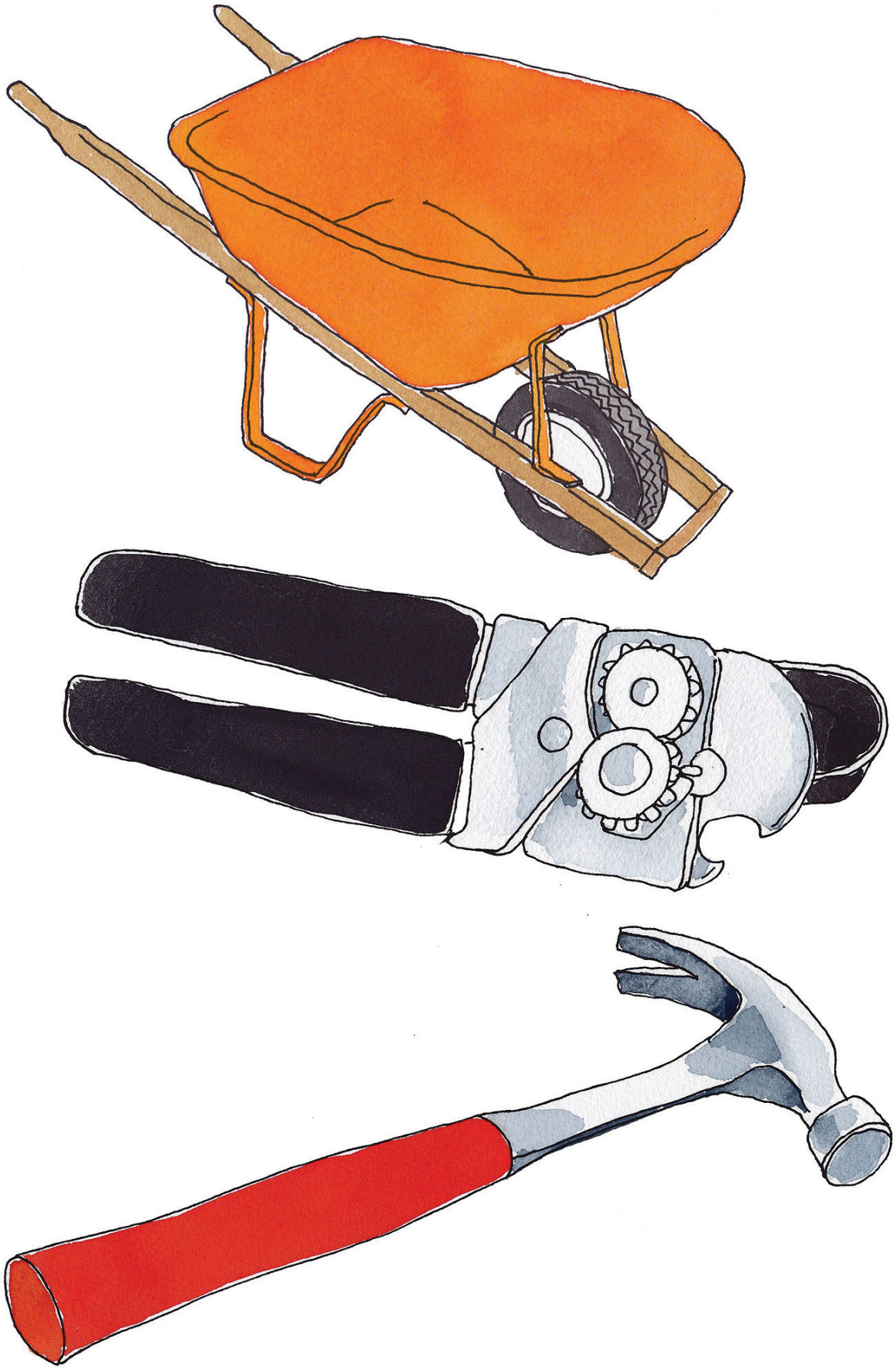


Pulley Extension/Teacher Demonstration

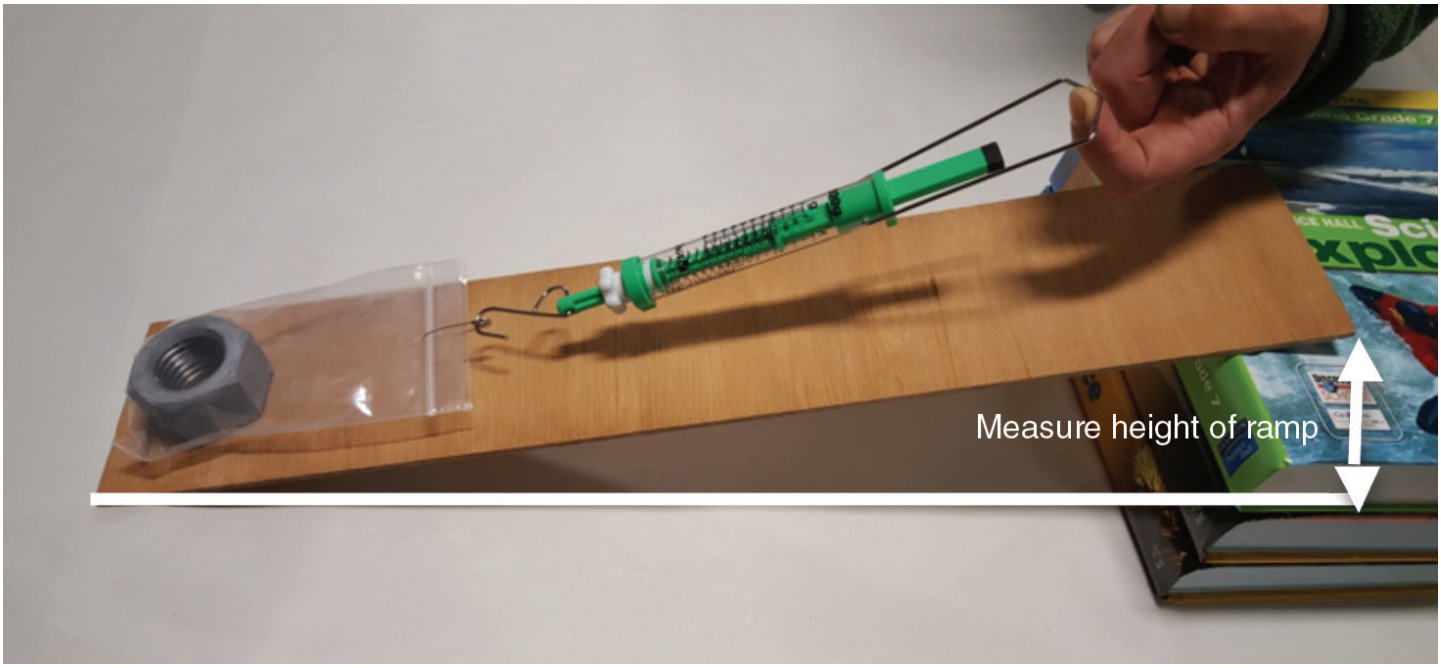
1. During part one, students were asked to predict how much force would be required to lift the weight if an additional pulley was added. Ask students to share their predictions and reasoning. **Hopefully students predicted it would require less force than than the amout needed to lift the weight with two pulleys.**

2. Follow the drawing at right, and using the double tandem pulley included with the kit, demonstrate a three pully system for the class. Determine the force required and share the results with the class.

3. **Adding more pulleys causes you to pull more string through the system to lift the weight. The more string you pull, the less force you need to lift the weight.**



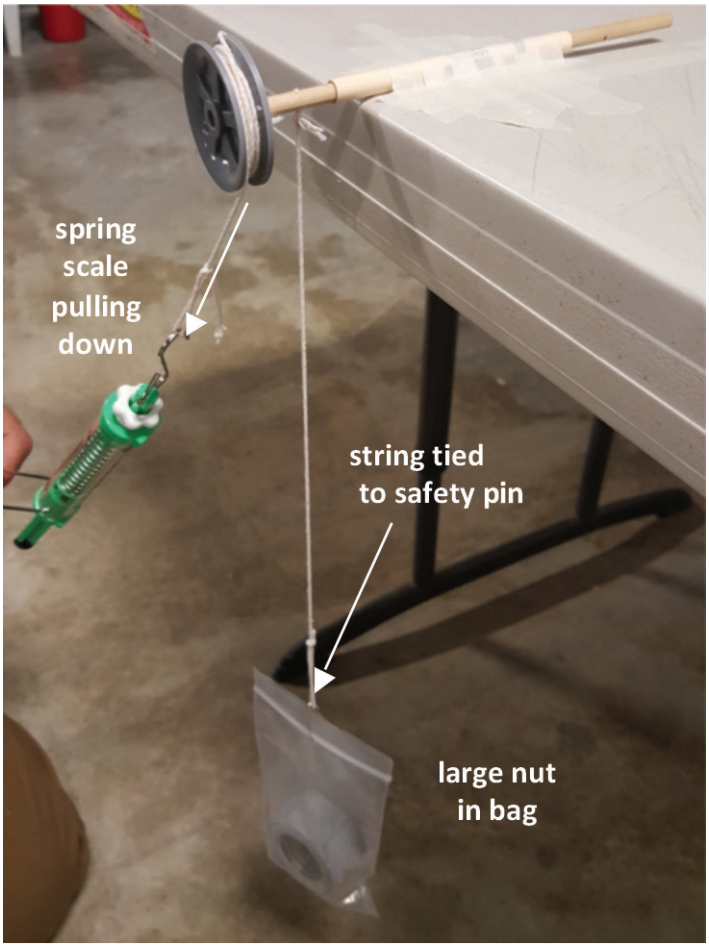
INCLINED PLANE STATION DIRECTIONS



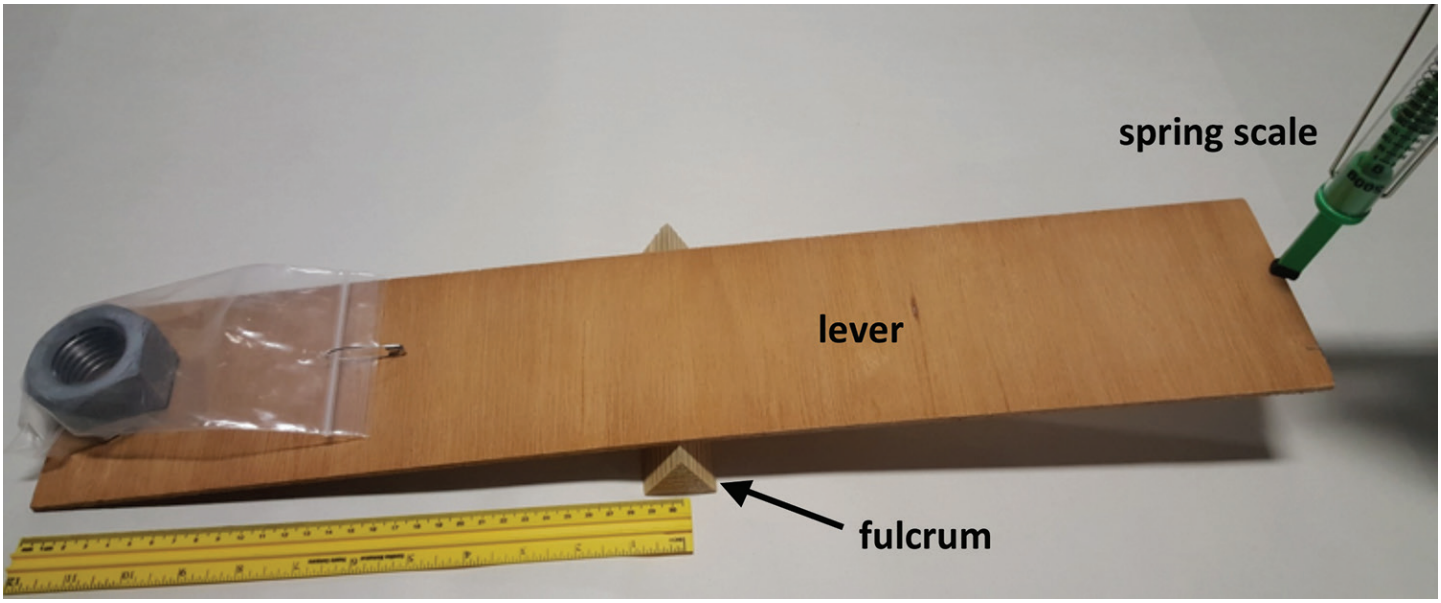
1. Use the spring scale to determine the force required to lift the weight in the bag WITHOUT using the inclined plane. Write this force on the student sheet.
2. Following the illustration, change the height of the ramp by adding or removing books, and use the ruler to measure three different heights. For each height, measure the amount of force needed to drag the weight up the ramp.
3. Record the three different heights and forces required on the student sheet.
4. Determine which height makes it easiest to lift the weight. Circle the force required to lift that weigh on the student sheet.
5. On the student sheet, write how to make the inclined plane use the least force to lift the weight.

WHEEL AND AXLE STATION DIRECTIONS

1. Use the spring scale to determine the force required to lift the weight in the bag WITHOUT using the wheel and axle. Write this force on the student sheet.
2. Following the illustration, determine how much force is needed to lift the weight using the wheel and axle. Record the result on the student sheet.
3. Measure the distance in cm that you must pull the string to lift the weight 5 cm.
4. Fill in the forces and distances on the student sheet for this station, and answer the two questions.

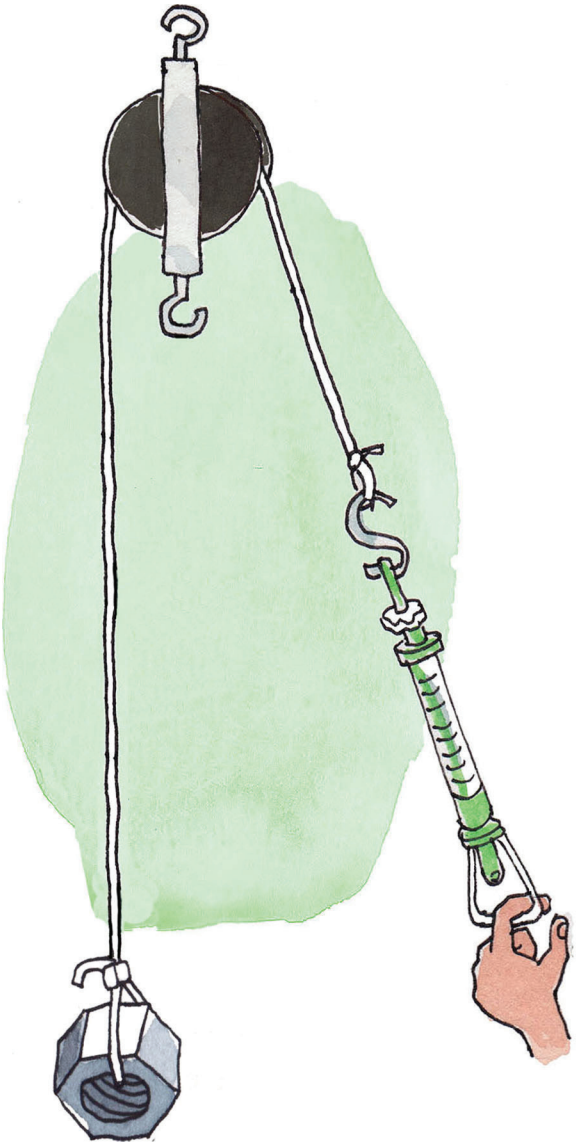


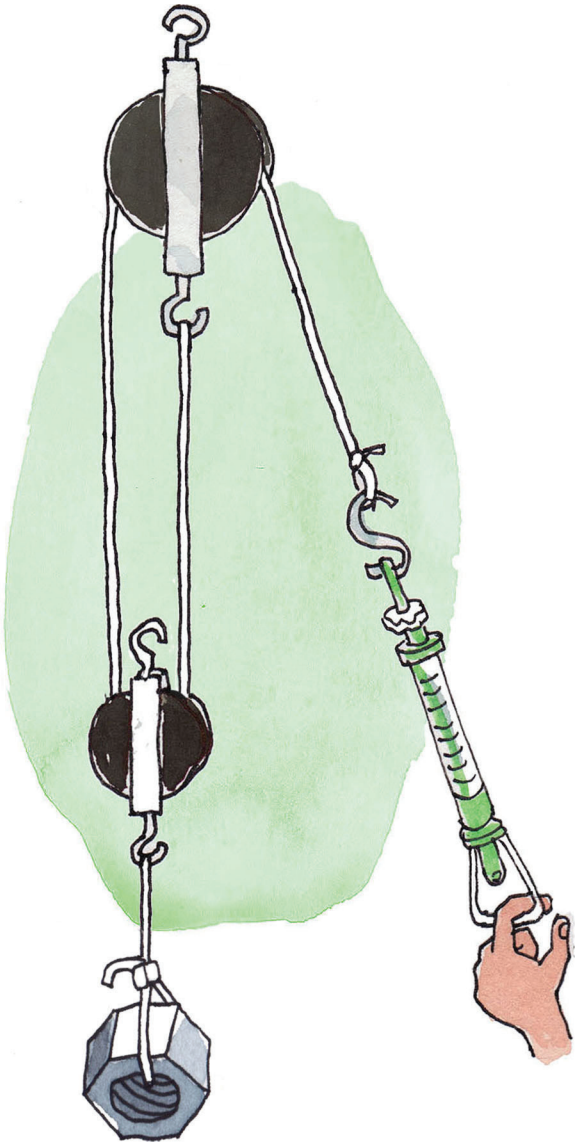
LEVER STATION DIRECTIONS



1. Use the spring scale to determine the force required to lift the weight in the bag WITHOUT using the lever. Write this force on the student sheet.
2. Following the illustration, place the fulcrum somewhere near the middle of the lever. Use the rubber tip end of the spring scale to push down on the lever on the end opposite from the weight. Push until the weight lifts off the table. Notice how much force was required.
3. Use the ruler to place the fulcrum 30 cm from the edge of the lever with the weight. As in step 2, determine the force needed to lift the weight with the lever. Record the force required to lift the weight on the student sheet in the 30 cm column.
4. Repeat step 3 for 20 cm and 15 cm from the edge of the lever with the weight. Record the forces required to lift the weight on the student sheet in the 20 cm and 15 cm columns.
5. On the student sheet, write how to make a lever use the least force to lift the weight.

PULLEY(S) STATION DIRECTIONS





1. Use the spring scale to determine the force required to lift the weight in the bag WITHOUT the pulleys and write it on the student sheet.
2. Following the illustration on the left for the single pulley, determine the force required to lift the weight and record it on the student sheet.
3. Remove the weight and spring scale. Add a second pulley to set up the double pulley as shown in the illustration on the right above. Determine the force needed to lift the weight and record it on the student sheet.
4. Predict how much force would be required to lift the weight if you added another pulley, for a total of three. Give a reason for your prediction.

Student Sheet Side 1 NAME_____

INCLINED PLANE

Force needed to lift weight without the inclined plane:_____grams

distance of top of ramp above table	**_____cm**	**_____cm**	**_____cm**
force needed to move the weight up	**_____grams**	**_____grams**	**_____grams**

How you would use the inclined plane to lift the weight with the least force:

_____

_____

_____

_____

WHEEL AND AXLE

Force needed to lift weight without the wheel and axle:_____grams

Force needed to lift weight with the wheel and axle:_____grams

Distance pulled, in cm of string, needed to lift the weight 5 cm:_____cm

How did the distance you pulled the string compare to how high you lifted the weight?

_____

How did the force required to lift the weight without the machine compare to the force needed with the machine?

_____

Student Sheet Side 2 NAME_____

LEVER

Force needed to lift weight without the lever:_____grams

distance between the end of the lever with the weight and the fulcrum	15 cm	20 cm	30 cm
force needed for lever to lift weight	_____grams	_____grams	_____grams

How you would make the lever use the least force to lift a weight:

_____

_____

_____

_____

PULLEYS

Force needed to lift weight without the pulleys:_____grams

force needed to lift weight with a single pulley	_____grams
force needed to lift weight with a double pulley	_____grams

Predict how much force would be required to lift the weight if you added another pulley, for a total of three. Give a reason for your prediction.

_____

_____

_____

_____