unit 25

Simple Machines, Complex Inquiry
What is work and how can we make work easier?

How do we make the best ramp?

How do wheels and pulleys make work easier?

How can we creatively combine simple machines to save even more work?

What is work? What is friction and how does it affect force?

How do wheels affect force and work?

How can we choose the best simple machine for the job?

How do you know if forces are balanced or unbalanced?

Does the angle of the inclined plane affect force?

Does the angle that you pull the pulley rope change the amount of force?

How do engineers combine simple machines to create amazing and complex creations?

How do different types of levers make work easier?

How are wedges and screws similar to inclined planes?

DEIGN CHALLENGE: Can we design a compound machine to perform a simple task?
<table>
<thead>
<tr>
<th>Lesson</th>
<th>Inside MySci kit, you’ll find:</th>
<th>Items you must supply:</th>
<th>Extra prep time needed:</th>
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</thead>
</table>
| Lesson 1 | Simple Machine Cards | Science notebooks & internet access 6 copies of the same textbook for work scenarios 2 identical objects that are safe for students to throw | Review MySci Safety Guidelines  
Copy and administer the pre-assessment  
Copies of the Work Scenarios Handout (Appendix i)  
OPTIONAL: Copies of the Extend Handout (Appendix iii) |
| Lesson 2 | 6 spring scales  
6 wooden Levers  
6 weights  
6 fulcrums (spools)  
6 tape measures | Science notebooks & internet access  
OPTIONAL: A computer/tablet with internet access for each student or pair of students (Extend section) | Copies of the Independent/Dependent Variable handout (Appendix vi)  
Copies of the “Spring Scales and Balance” handout (Appendix viii-ix)  
Copies of the Elaborate and Evaluate Questions (Appendix x)  
OPTIONAL: Make sure that the phet simulation works on your computer(s) for Extend section |
| Lesson 3 | Papa’s Mechanical Fish by Candace Fleming  
Simple Machine Cards from Lesson 1 | Science notebooks & internet access  
Post-It notes (Optional, but recommended) | Put Simple Machine Cards from Lesson 1 in order by number  
Number post-its on each page of the book so the students can see.  
Copies of the Evaluate Question (Appendix xii), 2 per sheet, and cut in half. |
| Lesson 4 | 6 boards  
24 binder clips  
Materials with different friction  
6 spring scales from Lesson 2  
6 weights from Lesson 2  
6 sets of magnets and washers (to add as weight)  
Tape | Science notebooks & internet access | Copies (double-sided, 2 sets) of the Data Recording Sheet (Appendix xiii-xiv)  
Copies of the Evaluate handout (Appendix xv) |
| Lesson 5 | 6 spring scales from Lesson 2  
6 boards from Lesson 4  
6 weights from Lesson 2  
6 wooden blocks  
6 protractors | Science Notebooks & Internet access  
Scissors  
OPTIONAL: Computer access for students (Extend section) | 6 Copies of the protractor handout (Appendix xvi)  
Copies of Evaluate Handout Appendix xvii), 2 per sheet, and cut in half.  
Textbooks or other items to prop up inclined plane  
OPTIONAL: Make sure that the phet simulation works on your computer(s) (Extend section) |
## Unit 25 Teacher Preparation List

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Inside MySci kit, you'll find:</th>
<th>Items you must supply:</th>
<th>Extra prep time needed:</th>
</tr>
</thead>
</table>
| Lesson 6 | Simple Machine Cards from Lesson 1  
Foam block  
Straight Stake  
Spiral Stake | Science notebooks | Copies of Regular Slide vs Spiral Slide (Appendix xviii)  
Put Simple Machine Cards from Lesson 1 in order by number |
| Lesson 7 | 6 toy trucks  
6 boards from Lesson 4  
6 weights from Lesson 2  
6 tape measures from Lesson 2  
6 blocks from Lesson 5 | Internet access | OPTIONAL: Copies of the Extend Data grid (Appendix xx) |
| Lesson 8 | 6 pulleys  
String  
6 weights from Lesson 2  
6 Spring scales from Lesson 2  
Tape from Lesson 4  
6 protractors from Lesson 5 | Scissors | 6 Copies of the protractor handout (Appendix xvi)  
Copies of the Pulley Angle Inquiry handout (Appendix xxi)  
OPTIONAL: Copies of the Spring Scale probe handout (Appendix xxi) and copies of the Extend Handout (Appendix xxi) |
| Lesson 9 | Simple Machine Cards from Lesson 1  
6 copies of *The Fort on Fourth Street: A Story About the Six Simple Machines* by Lois Spangler  
Graph paper | OPTIONAL: Materials for students to build their model designs | Put Simple Machine Cards from Lesson 1 in order by number  
Copies of the Active Reading & Inquiry Questions handout (Appendix xxiv) |
| Lesson 10 | *Papa's Mechanical Fish* by Candace Fleming from Lesson 3  
Materials from all previous lessons | Internet access  
OPTIONAL: Additional materials for students to use in their compound machines | Copies of the Listening Passage Handout (Appendix xxv)  
Copies of the Engineering Design Cycle (Appendix xxvi)  
Copies of the Project Rubric (Appendix xxvii)  
Copy and administer the post-assessment |
Lesson 1: What is work?

LEARNING TARGET
Define work and describe variables in a fair test that compare the amount of work being done.

SUMMARY
Students will observe and participate in a series of work scenarios to define and compare amounts of work.

ENGAGE
You hear someone say “I am working hard!” or “I am doing a lot of work!” What do you imagine the person is doing? Write your thoughts in your science notebooks. Include drawings if you’d like!

Discuss student ideas about the meaning of work. Ask students to share their drawings and ideas. Hopefully students will share out ideas of both physical work and mental work. While people might mean different things when they say they are working, there is a scientific definition of work that we will explore today.

EXPLORE
Hand out copies of the Work Scenarios handout (Appendix i). Tell students to leave the last two questions blank for now. Explain that for each scenario, we will try to see what stays the same (control variable), what is different (independent variable), and compare amounts of work done by each student (dependent variable). You can choose to discuss the results after each scenario or at the end of all scenarios.

Scenarios: For each scenario, get 2 volunteers to come to the front.

1. Each student gets a copy of the same textbook and must hold the book the same way. Ask them to walk slowly to the back of the room.
2. Hand one student one copy of a textbook. Give the other student 4 copies of that same book. Ask them to walk to the back of the room.
3. Hand each student a copy of the same textbook. Ask one student to walk to the middle of the room, while the other student must walk to the back of the room.
4. Hand each student a copy of the same textbook. Ask one student to walk slowly to the back of the room. Ask the other student to walk to the back of the room very quickly.
5. Hand each student a copy of the same textbook. Ask one student to walk to the back of the room. Have the other student stand there, holding the book.

MYSCI MATERIALS:
Simple Machine Cards

TEACHER PROVIDES:
Science notebooks
Internet access
6 identical textbooks for work scenarios
2 identical objects that are safe for students to throw and catch for work scenarios
Copies of the Work Scenarios Handout (Appendix i)
OPTIONAL: Copies of the Extend Questions Handout (Appendix iii)

Teaching Tip:
This icon highlights an opportunity to check for understanding through a formal or informal assessment

Teaching Tip:
The Work Scenarios handout answer key and discussion points are included in Appendix ii.

Teaching Tip:
Another option for presenting these work scenarios to your students is to present one scenario as a demo and then assign the remaining scenarios to small groups to analyze and present to the class.
Lesson 1 continued: What is work?

6. Hand each student a copy of the same textbook. Ask one student to simply hold the book. Ask the other student to lift the book up towards the ceiling as far as they can.

7. Hand each student a copy of the same textbook. Ask one student to simply hold the book. Ask the other student to drop (NOT THROW!) the book on the floor.

8. (For this scenario, you need four volunteers) Have each pair of students stand about eight feet apart, facing their partner. Give one student in each pair identical objects that are safe to throw. Have one student gently toss the object to their partner. Ask the other student to slowly walk over and hand the object to their partner.

9. Have one student carry one book and walk quickly to the back of the room. Have the other student carry four books and walk slowly to the back of the room.

EXPLAIN

Ask students to supply definitions of work and force.

ELABORATE
Explain that machines are useful if they make work easier. Select Card 45 (boat rudder) from the Simple Machine Cards deck and pass it around. Display these four questions and have students copy them in their science notebooks. Then, model these questions and answers for Card 45.

1. What is the tool being shown? (Answer: A boat rudder)
2. What work can it do? Describe the force and the distance it moves. (Answer: It helps to turn the boat left or right. The force is from the hand pushing on the rudder, the rudder moves through the water.)
3. What do you think people used before that tool was invented? (Answer: They might use oars or paddles, use a sail and go where the wind blows them, paddle with their hands, just go with the waves, etc)

If necessary, model another card for students, with them supplying possible answers and discussing them as a class. For Card 44 (hammer), possible answers to the questions above are:

1. A hammer
2. It helps to pound nails into wood or to pull out nails.
3. People might have used a rock.
Lesson 1 continued: What is work?

☑ Next, students will get one card (individually, in pairs, or in groups). Ask them to answer the three questions about their card or cards. When they are finished, have them share out to the class. You can decide how many cards to go through or start out in groups and move to individual student responses. It is not necessary to go through every card. The answer key for the Simple Machine Cards is in Appendix iv-v.

EVALUATE
☑ Ask students to answer the two questions at the bottom of the Work Scenarios handout (Appendix i). Discuss the answers as a class.
NOTE: Answers are in the answer key in Appendix ii.

EXTEND (OPTIONAL)
☑ To take your students’ thinking to the next level, an optional handout (Appendix iii) contains two advanced work scenarios. Hand out and allow students to justify their answers based on previous work. A Discussion Notes section is provided on the handout for students to revise their answers based on the class discussion.

Teacher guide for student responses (Question 1): In the eyes of the teacher, both students did the same amount of work; they moved the book from the front of the class to the back of the class. The displacement (start to finish) is the same. The student who went straight was efficient in their work. The student who went all around the room traveled a greater distance to do the task, but it is because they were not efficient. That student did move the book more distance overall, but in the end, the book just went from the front to the back (same displacement).

Teacher guide for student responses (Question 2): This is a tricky one! In the eyes of the teacher, it is easy to see that the first student did the job that was asked, while the second student didn’t. The first student moved the book through a displacement (start to finish). However in the eyes of the teacher, the second student did NO work. They moved the book NO distance (start to finish). Therefore, the first student did work and the second student didn’t. Another way to think about displacement is this: If your eyes were closed while the students were moving, then you opened your eyes when you were done, it would look like the first student did work while the second student didn’t move at all. Their displacement is zero so the work is zero.

Teaching Tip:
You could also choose to do a gallery walk of student responses, or have students try to make groups based on which machines work in similar ways.
Lesson 2: How do you know if forces are balanced or unbalanced?

LEARNING TARGET
Design an experiment to recognize and describe situations when forces are balanced and unbalanced.

SUMMARY
Students will use a simple lever setup to measure balanced forces with a spring scale.

ENGAGE
Who can describe a seesaw or teeter totter? What does it look like and how does it work? Take student answers. Sketch a simple seesaw on the board. Introduce the vocabulary words “lever” and “fulcrum”.

As we watch the two videos, look for balanced and unbalanced forces. How do you know when forces are balanced or unbalanced? Write your thoughts in your science notebook. You can include a diagram, but be sure to also explain it!

Quadruplets: https://www.youtube.com/watch?v=P3VeRJMd2MY
Family on log: https://www.youtube.com/watch?v=zkp8yflPzbQ

Share student answers. If no one says that the people on the seesaw are not moving when forces are balanced, ask “If the seesaw is perfectly balanced, are the people moving?” Ask students if they would ever expect to see a full-grown person being balanced by a small child? Is this even possible? What about a full-grown elephant being balanced by a small mouse?

After the discussion, tell students that both of these things ARE possible and today we will see how.

EXPLORE
Introduce the vocabulary for fair test, control variable, independent variable, and dependent variable in Appendix xviii.

Then, hand out copies of the independent and dependent variable worksheet (Appendix vi). Note: The answer key for this worksheet is in Appendix vii. Model the example question for the students, then have them work in pairs or groups to complete the first question. Finally, have them individually work on the second question. When students have finished, share and discuss answers.

EXPLAIN
Today we will use two pieces of equipment to make measurements. One is a tape measure and the other is a spring scale. What do we measure with each of these items?

Teacher guide for student responses: Take student responses to understand their familiarity with these devices. If necessary, explain which side of the tape measure (inches or cm) to use. Students may say that the spring scale measures weight or mass. Demonstrate how to read the spring scale by hanging a weight from it. Guide students to the understanding that the spring scale measures force on the hanging weight. What is providing the force? Gravity!
Lesson 2 continued: How do you know if forces are balanced or unbalanced?

The spring scale gives us a way to measure the force that will balance the lever. Hand out copies of the Spring Scale and Balance handout (Appendix viii-ix). Work through the top part of the handout with students, highlighting the guiding questions and labeling the diagram. Then, discuss the control, independent and dependent variables. Why did we choose these things for our variables?

Have students set up and complete the experiment. The half-meter stick has a hold drilled in one end to hook with the spring scale. Place the fulcrum at about the 18 cm mark on the stick, and measure from that mark to the middle of the weight (the hook on top). Have them record and graph their data either on the handout or on an online graphing site such as: http://nces.ed.gov/nceskids/createagraph/

ELABORATE

Watch NASA Our World: Science at the Circus: http://ia801407.us.archive.org/2/items/nasa_flv/NASA_Science_Earth_Clip26_HD_512kb_512kb.mp4. You may want to stop the video at the 1:53 mark. After you’ve finished watching the video, ask the students if they saw a time in the video when forces were balanced? If so, how do they know that the forces were balanced?

Teacher guide for student responses: In order for forces to be balanced, there needs to be no motion. Are the people ever still?

EVALUATE

Ask students to complete the Evaluate questions on the handout. Answers:

1. The independent variable is the distance between fulcrum and the weight. We changed this to see what would happen.

2. The dependent variable is the force that it took to balance the weight. We measured this using the spring scale, and it changed depending on where the weight was placed.

3. The weight (how heavy it was) and the distance it was between the fulcrum and the spring scale. We also used the same lever, fulcrum, and spring scale.

4. The mouse would be very far away from the fulcrum and the elephant would be very close to the fulcrum.

Hand out a copy of the Evaluate handout (Appendix x). The answer key to this worksheet appears in Appendix xi. Ask students to respond only to the Elaborate question. When students are finished, group them to discuss their answers. They should use Claim/Evidence/Reasoning to attempt to convince their peers. Then, do a whole-room share out. Push students to use academic vocabulary and relate their answers to the experiment.
Lesson 2 continued: How do you know if forces are balanced or unbalanced?

EXTEND (OPTIONAL)
This simple balance beam game (http://phet.colorado.edu/en/simulation/balancing-act) will give students practice on balancing, predictions and finding missing masses. There are three tabs at the top of this game (Intro, Balance Lab, Game). Demonstrate the basic use of the program in the first two tabs before you give the students their own computers to start. Students should all start the game on Level 1. Each level is six questions. They get two points for getting it correct on the first try and one point for getting it right on the second try.

Teaching Tip:
If it is not possible for your class to access computers for every student, project the questions one at a time and have the class work through them together. Remind your students that they can use the simulation on any computer, any time, for more practice.
Lesson 3: How do different types of levers make work easier?

LEARNING TARGETS
Identify levers in everyday objects.
Identify the force, load and fulcrum of levers.

SUMMARY
Not every lever will look like a seesaw. Students will learn how to identify levers in everyday objects.

ENGAGE
Draw a basic seesaw like we used in the last lesson. Label the fulcrum, the load, and the force.

This is one type of lever, called a Class 1 lever. It has the fulcrum in the middle between the load and the force. There are two other kinds of levers that have different arrangements. What do you think they might look like? Make a hypothesis about what the other two types of levers look like and draw sketches of them.

Discuss student responses. One should have the fulcrum on one end next to the load, and the other should have the fulcrum on one end next to the force.

EXPLORE
Show basic diagrams of the 3 classes of levers. Guide students to take notes in their science notebooks on the force, load, and fulcrum of each kind of lever. http://www.enchantedlearning.com/physics/machines/Levers.shtml

Give 1 real-world example of each from the set of Simple Machine cards:
Card 35: Seesaw (Class 1 Lever): Use videos from Lesson 1 or the experiment from Lesson 2 as examples/reminders
Card 22: Wheelbarrow (Class 2 Lever): Show the picture. Explain that when you lift the handles (force), the load (whatever is in the wheelbarrow) rises up and the wheel part is the fulcrum.
Card 32: Hockey Stick (Class 3 Lever): Here is a video, Hockey Shots in Slow Motion: https://www.youtube.com/watch?v=Nz_41e6ppM. Notice the top hand doesn’t move much or at all (fulcrum). The hand in the middle is providing the force or effort. The load is the puck.

EXPLAIN
So far, we’ve talked about levers. Levers are one kind of “simple machine”. We’re going to talk about 5 other simple machines, but right now we’re going to read a story about a very, very complicated machine! As we read the story, can you identify any levers in the story?

Read “Papa’s Mechanical Fish.” Encourage the students to take notes as you read and show them the book. Pause on the page that shows the family eating socks. Do they see a lever? A fork is a lever! The load is the food. The fulcrum is the part of your hand that doesn’t move. The force

MYSCl MATERIALS:
Papa’s Mechanical Fish by Candace Fleming
Simple Machine Cards from Lesson 1

TEACHER PROVIDES:
Science notebooks
Internet access
Post-it Notes (optional but recommended to number the pages in the book)
Copies of the Evaluate Question (Appendix xii), 2 per sheet, and cut in half.

Teaching Tip:
At this grade level, it is not usually necessary for students to identify which class of lever each simple machine represents. However, if you would like to extend your students’ efforts, you can ask them to make this classification. The simple machine cards answer key in Appendix iv-v includes the lever classes.

Teaching Tip:
This book does not have page numbers, but you could number post-it notes and place them on each page. This will make it easier for students to identify where they saw each lever in the book. This will also help a lot in Lesson 11, when students revisit this book.
Lesson 3 continued: How do different types of levers make work easier?

is applied by the part of your hand that does move. Push them to find other levers in the book. Hopefully they will spot hammers, fishing poles, control levers on the fish, an oar, etc.

ELABORATE
Put the students into six groups. Model finding the force, load, and fulcrum with Card 45 (boat rudder). The force is applied by the hand. The load is the water pushing on the rudder. The fulcrum is on the edge of the boat. Hand out the Simple Machine Cards so that each group gets seven cards. Find all of the cards that show levers.

After each group has finished, have them share out to the whole class. They should explain which cards are levers and which cards they have that are not levers. When the group is done presenting, ask the other students if they agree. Use the answer key in Appendix iv-v to check student work.

Once each group has identified the levers in their set of cards, ask them to identify the load, the fulcrum, and the force for each lever.

EVALUATE
Hand out copies of the Evaluation Question (Appendix xii). The hand is the force, the edge of the crate is the fulcrum and the lid of the crate is the load.

Teaching Tip:
If you arrange the cards by number and hand out 7 cards to each group in order (that is, Group 1 gets Cards 1 - 7, Group 2 gets Cards 8 - 14, etc), this will ensure that each group has at least 3 levers. You won’t use Cards 43, 44, or 45 and that is OK!
Lesson 4: What is friction and how does it affect force?

LEARNING TARGET
Describe how friction affects the amount of force needed to do work.

SUMMARY
Students will experiment to see how much force is required to drag a weight over different level surfaces.

ENGAGE
Is it easier to pull your friend in a sled on the bare sidewalk or on a snowy sidewalk? Why?

Take student responses. Push students to recognize what stays the same (the sled is the same, the passenger is the same) and what is different (the surface). Guide students to the idea of pulling harder meaning that you need more force. If you need more force, there must be more friction because of the surface. Less force means less friction.

EXPLORE
Today we are going to do an experiment to measure the force needed to pull objects across different surfaces. First, demonstrate to students how to steadily pull the weight over the surface and read the spring scale. Make sure you show them how to pull gently, parallel to the ground, just until the object starts to move.

Now, we have to decide what to keep the same in our experiments (control variables), what we should change (independent variable) and what we should measure to see if it changes (dependent variable). Hand out copies of the Data Recording Sheet for this lesson (Appendix xiii-xiv).

Lead the students in a discussion of the variables. Give students this list of variables and ask them to assign each one as a control variable, independent variable or dependent variable. Answers are below.

Variable List:
The material on the surface of the ramp, the weight, the force on the spring scale, level ground, type of spring scale used.

Answer Key:
Control Variables: we all have the same weight, we will all experiment using level ground, we all use the same spring scale
Independent variable: the surface we are dragging the weight across
Dependent variable: the measurement of force on the spring scale

MYSCI PROVIDES:
6 boards
24 binder clips
Materials with different friction
6 spring scales from Lesson 2
6 weights from Lesson 2
6 sets of magnets and washers (to add weight)
Tape

TEACHER PROVIDES:
Science notebooks
Internet access
Copies of the Data Recording Sheet (Appendix xiii-xiv) (Note: double-sided, two sets needed)
Copies of the Evaluate question handout (Appendix xv)

Teaching Tip:
This lesson will take more than one day. For example, you may choose to do Engage and Explore on Day 1, Explain on Day 2, and Elaborate and Evaluate on Day 3.
**Lesson 4 continued:** What is friction and how does it affect force?

Next, guide your students as they write a testable question. The testable question should be in the form "How can changing (independent variable) affect (dependent variable) when (control variables) are held constant?" Then, they should make a prediction based on the materials they are going to test.

**EXPLAIN**

Give each group of students a set of materials for the experiment (spring scale, inclined plane, material samples, 4 binder clips, 1 weight). Have students perform the test, recording their results on the handout. In addition to testing the materials, they can also test both sides of their board without any materials attached.

Once students are finished, they should construct a bar graph showing the independent variable on the x-axis (different material types) and the dependent variable on the y-axis (force).

When all students are done, compile the results from each team for each material. Do the results agree? Have the class put the materials in order from lowest friction (lowest force) to highest friction (highest force). Have students record and discuss this question: Which material would you want to pull an elephant on a sled on? Why?

**ELABORATE**

Now, you will design an experiment to test how a different amount of weight changes the amount of force it takes to move up the ramp. Give each team 3 of the metal slugs. Hand out new copies of the Data Recording Sheet. Ask them to come up with the control, independent and dependent variables in their teams. Make sure that they can explain their choices and understand how they are different than the previous experiment. Before going forward with the experiment, make sure all students understand the variables.

- **Control Variables:** each team will choose one surface material; all will work on a level surface
- **Independent variable:** the different amount of weight
- **Dependent variable:** the amount of force required

Show the students how to attach the slugs one at a time to compare the force required to move the weight. Have students record their results on a new copy of the Data Recording Sheet handout (Appendix xiii-xiv). They can plot their results as a line graph or a bar graph.

**EVALUATE**

To evaluate student understanding of this lesson, hand out copies of the Evaluate questions (Appendix xv). Answers:

A. The first force is less than the second force because friction is lower on ice than on a parking lot.

B. The first force is greater than the second force because the weight of 100 books is greater and it takes more force to move a greater weight.

**Teaching Tip:**

It is up to you to decide how you will assign the different ramp materials. You may have each group test one material, teach group test and compare 2 different materials, or have every group test every material. Be sure to compile and compare data regardless of how you have your students test.
Lesson 4 continued: What is friction and how does it affect force?

EXTEND (OPTIONAL)
If you would like to extend this lesson with more hands-on experiments, have students brainstorm other items that they think will have higher and lower friction than the items in the kit. They can bring items from home or use items from the classroom. In addition to changing the material on the ramp, students could also change the material of the weight by wrapping a new material around it. Then, they could test combinations of materials (sand paper weight on sand paper ramp versus foil weight on foil ramp).
Lesson 5: Does the angle of the inclined plane affect force?

LEARNING TARGET
Describe the relationship between the angle of the inclined plane and the force needed to move an object.

SUMMARY
Students will design an investigation to determine if the angle of an inclined plane affects the force required to move an object.

ENGAGE
Is it easier or more difficult to pull or push something on level ground or up an inclined plane (ramp)? Can you use the word “force” in your answer?

Teacher guide for student responses: Hopefully students recognize that it is more difficult to push or pull something up a ramp than on level ground.

EXPLORE
Does the angle (steepness) of the ramp matter? We measure steepness in degrees. Flat ground has an angle of zero degrees. How many degrees for something that is straight up and down, like a wall? (90 degrees). Explain that today the students will prop up an inclined plane and measure the angle with a protractor. Then, they will measure how much force it takes to pull the weight up the ramp.

Lead a discussion on how the students will set up data collection sheets and have them make data collection sheets in their science notebooks. (They can use the data sheets from the previous lessons as a guide, but push them to come up with the variables on their own and be sure that they are making a prediction!) What is the independent variable, and how do you know? (ramp angle, because we are changing it) What is the dependent variable, and how do you know? (force, because we want to measure it and see how it changes when we change the ramp angle) What are some control variables? (each group will use the same weight each time; each group will select a ramp material and use that material throughout the experiment)

Give the students a chance to experiment with the protractor first, before you begin the experiment. Give each group a copy of the Protractor handout and have them carefully cut out the protractor. Be sure that students know how to line up the corner of their protractor with the end of the ramp and the 0 line of the protractor with the desk. Set up a ramp at the front of the class and have each group come up and measure the angle, then compare results to ensure that all groups understand how to measure the angle.

EXPLAIN
Have students do the experiment and record their data. Be sure to circulate and make sure they are using the protractor and spring scale correctly. The spring scale should be gently and steadily pulled along the inclined plane, parallel to the inclined plane.

MYSCI MATERIALS:
6 wooden blocks
6 protractors
6 spring scales from Lesson 2
6 boards from Lesson 4
6 weights from Lesson 2

TEACHER PROVIDES:
6 copies of the protractor print-out page (Appendix xvi)
Copies of the Evaluate Question (Appendix xvii), 2 per sheet
Textbooks or other items to prop up the inclined planes
Science notebooks
Internet access
Computers for student use (Optional)

Teaching Tip:
If the discussion of variables is difficult for students, ask if we could change both the ramp angle and the material each time and then compare the results. How would we know if the change in results was because of the angle changed or the material changed?
Lesson 5 continued: Does the angle of the inclined plane affect force?

After they have collected data on at least 5 different angles, ask them to create a graph of their results. You can ask them to do this in their science notebooks or use an online graphing site such as: http://nces.ed.gov/nceskids/createagraph/

Be sure that they set up the independent variable (angle) on the x-axis and the dependent variable (force) on the y-axis.

When all groups are ready, ask them to explain their experimental setup (including which material they used) and show their graph. In general, did the class agree? Does the angle of the inclined plane affect force? How does it affect the force?

ELABORATE

Put students into pairs with a student from a different group. Have them examine the data they collected in the experiment. How is it similar? How is it different? Did they reach the same conclusions?

EVALUATE

Hand out copies of the “Evaluate” question (Appendix xvii). After students have completed the question, lead a class discussion of their answers.

Teacher guide for student responses: Students may say that it is a good design because it would be fun to go down this ramp. If so, ask them if it would be easy to go up the ramp in a wheel chair. Hopefully some students point out that it is very steep and would be difficult to go up. They may also discuss the friction on the ramp based on previous lessons. Ways to improve the ramp may include to make it less steep. If this is the case, push students to understand that the ramp would then need to be longer.

EXTEND (OPTIONAL)

This computer simulation (http://phet.colorado.edu/en/simulation/the-ramp) allows students to gain a deeper understanding of the mathematics of force. The force of friction is a negative value and you must apply enough force to overcome it. Although more information is provided in the demo than is covered in this lesson, students can experiment with different combinations of ramp angle, mass and force.
Lesson 6: How are wedges and screws similar to inclined planes?

LEARNING TARGET
Identify wedges and screws in every day objects.

SUMMARY
Students will participate in a classroom demonstration of a straight and spiral stake (nail versus screw).

ENGAGE
Hold up the two different stakes (dog leash stake and tent stake). Ask students if they know what the objects are and what they are used for. How are they the same and how are they different? Take student answers.

EXPLORE
The Explore section is a demonstration. Ask the students which stake they would choose to attach your dog’s leash if you had to leave your dog in the yard. Why are they making that choice? Students can discuss whole group or with partners and then share out ideas.

Put tent stake and dog leash stake in the foam or have a student assist you. The straight stake can be pushed straight in, but you will have to screw the spiral stake into the foam. As the students which one is easier to put into the foam.

Next, firmly hold the foam down to the desk and ask a student to come and pull on each stake. Which one is easier to pull out of the foam and why? Ask the students to discuss with one another which would be better for the task and why, noting why they changed their mind if they did. When the group shares out it will be important for them to identify why there is a difference in the two stakes.

EXPLAIN
The straight stake is an example of a wedge. A wedge has a pointed end and looks like two inclined planes. The spiral stake is an example of a screw.

Ask the students to look around the room and give examples of wedges and screws in the classroom or school. Discuss the function of the different examples given.

ELABORATE
Hand out the Regular Slide vs Spiral Slide handout (Appendix xviii). After students complete their ideas, lead a discussion about the similarities and differences between the two slides. While your students may come up with other similarities and differences, some are listed below. The most important difference to make sure they understand is that the spiral slide takes up less room while the regular slide is longer and takes up more room.

MYSCI MATERIALS:
Simple Machine Cards from Lesson 1
Foam block
Straight Stake
Spiral Stake

TEACHER PROVIDES:
Science notebooks
Copies of Regular Slide VS Spiral Slide handout (Appendix xviii)

Teaching Tip:
If you arrange the cards by number and hand out 7 cards to each group in order (that is, Group 1 gets Cards 1 - 7, Group 2 gets Cards 8 - 14, etc), this will ensure that each group has a good variety of cards.
Lesson 6 continued: How are wedges and screws similar to inclined planes?

Teacher guide for student responses:

<table>
<thead>
<tr>
<th>Straight Slide</th>
<th>Both Slides</th>
<th>Spiral Slide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight</td>
<td>Same color</td>
<td>Curved</td>
</tr>
<tr>
<td>Takes up more space (longer)</td>
<td>Same ladder</td>
<td>Takes up less space (because of the curve)</td>
</tr>
<tr>
<td></td>
<td>Same height</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Both are inclined planes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Made of the same materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Both used for fun</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Both get people safely to the ground</td>
<td></td>
</tr>
</tbody>
</table>

Answer key:
1. inclined plane
2. screw
3. Both slides get the person from the top to the bottom safely.
4. Student answers will vary; accept all reasonable answers as long as they are justified. For example, they might say the spiral slide is better because it is more fun.

EVALUATE

Revisit the card sort. Now, we are looking for Class 1, 2, and 3 levers, inclined planes, wedges and screws.

Put the students into six groups. Hand out the simple machine cards so that each group gets seven cards. Ask them to answer this question: Which of the cards show levers, inclined planes, wedges or screws?

After each group has finished, have them share out to the whole class. They should explain which cards are which simple machine and which cards they have that do not fit in one of these categories. When the group is done presenting, ask the other students if they agree. Use the answer key in Appendix iv-v to check student work.

EXTEND (OPTIONAL)

Design a spiral or straight ramp for a parking garage. Write a rationale for why you designed your ramp the way you chose.
Lesson 7: How do wheels affect force and work?

LEARNING TARGET
Describe how wheels make work easier by reducing friction.

SUMMARY
Students will revisit their friction experiments and add a trial with wheels.

ENGAGE
Many Native American cultures used pulled their belongings in sleds called “travois.” Sometimes they used dogs or horses to pull the sleds, too. Here is a drawing of a travois. Show only the first picture (Appendix xix). What kind of simple machine is it?

How might you improve this to make it easier for the dog to pull? Take student responses.

Here is one solution by a kid engineer. Show the second picture (Appendix xix). Why do the wheels make it easier to pull? Wheels make things easier by reducing friction. You can pull the same amount of weight with much less force.

Watch this video: https://www.youtube.com/watch?v=sirA64d6OVo or have students read this article: https://www.engineeringforchange.org/news/2012/03/20/a_12_year_old_engineer_designs_a_life_saving_travois_for_refugees.html

EXPLORE
Set a toy car on flat ground. Ask the students: Why isn’t this car moving? Everything requires an unbalanced force to move. If I push the car, it moves easily. Turn the car over on its roof and repeat. The car moves, but not as far. Today you will do an experiment to measure how much of a difference wheels make.

EXPLAIN
For our experiment, we will send the car down the ramp on its roof and then on its wheels and see how far it goes. Since friction slows things down, less friction should mean a longer distance. First, we have to plan our experiment. Identify the control, independent, and dependent variables for this experiment. How do you know that these variables are correct?

Lead students in a discussion to define the variables. Allow them to propose variables and use claims/evidence reasoning to support their choices.

MYSCI MATERIALS:
- 6 toy trucks
- 6 boards from Lesson 4
- 6 tape measures from Lesson 2
- 6 weights from Lesson 2
- 6 wooden blocks from Lesson 5

TEACHER PROVIDES:
- Internet access
- OPTIONAL: Copies of the Extend Data Grid (Appendix xx)
Lesson 7 continued: How do wheels affect force and work?

Control variables: Same car (same weight), same ramp, same ramp angle, same ramp material each time

Independent variable: Whether the car is on its wheels or on its roof

Dependent variable: How far the car travels from the end of the ramp

Have students make their own data table, make a prediction and compare the results. Share out as a class. What have you learned about how wheels reduce friction?

ELABORATE

Now we will test something else. Do you think the car will go further with or without a weight in the back of it? Why do you think that? Take student responses. Once again ask them to define the variables (and how they are the same and different as in our last experiment).

Control Variables: Same car on its wheels, same ramp, same ramp angle, same ramp material each time.

Independent Variable: If the car has the weight or not

Dependent Variable: How far the car travels from the end of the ramp

Have students make their own data table and compare the results. Share out as a class. What have you learned about how wheels reduce friction?

EVALUATE

Inventors and engineers have added wheels to everyday objects like shoes and furniture. Describe the advantages and disadvantages of adding wheels to either a shoe or a chair, and how they make work easier.

Teacher guide for student responses: Students should recognize that adding wheels allows things to move easier (such as furniture) or go faster (like roller blades). However, wheels make it difficult to stop or stay still. Students should recognize that it allows things to move easier due to a decrease in friction.

EXTEND (OPTIONAL)

You can have students reverse the direction of this experiment and pull the

Teaching Tip:

A steep ramp angle of about 30° or more works best. Otherwise, the car may not move at all when it is on its roof.
Lesson 8: Does the angle that you pull the pulley rope change the amount of force?

LEARNING TARGET
Explain how a single pulley can change the direction but not the amount of force needed to move an object.

SUMMARY
Students will perform an inquiry piece to determine if pulling the rope of a single pulley at different angles impacts the amount of work required.

ENGAGE
You need to lift a fragile crate of dishes up onto the roof of a building for a fancy roof-top party. The rooftop is much higher than your head. The crate is too big to take up the stairs or in the elevator. It won’t even fit in the door! How can you get the crate to the roof?

Teacher guide for student responses: Hopefully students mention a crane; although, they may also say a helicopter or by taking the dishes out of the crate and carrying them up the stairs a few at a time.

EXPLORE
Hand out copies of the Pulley Angle Inquiry handout (Appendix xxi). Complete Section 1 with your students.

Ask each group to complete Parts II and III of the handout. Before giving each group their equipment, meet with them to discuss their setup. Use the tape from Lesson 4 and a short piece of string to secure the pulley to the edge of the desk. Have them create their own data recording sheet for use in their experiment. Each group will also need one copy of the protractor page. Be sure that students have correctly identified the variables as follows:

- Independent variable: The angle that you pull the string
- Dependent variable: The force required to pull the string
- Control variables: same pulley, same string, same weight

EXPLAIN
Share out the results. Which prediction is correct? (Note: the amount of force should not change with the string angle.)

ELABORATE
If a single pulley doesn’t change the amount of force needed to move an object, why is it useful?

Teacher guide for student responses: Possible answers include, it changes the direction of the force, so that you can pull down (like at a bucket in a well) in order to move something up. You can also lift something up higher than your head if you have a pulley set up above you. It also allows you to stand off to the side if you’re lifting something heavy so that it doesn’t fall on your head!

MYSCI MATERIALS:
- 6 pulleys
- String
- 6 weights from Lesson 2
- 6 spring scales from Lesson 2
- Tape from Lesson 4
- 6 protractors from Lesson 5

TEACHER PROVIDES:
- Scissors
- 6 copies of the protractor print-out page (Appendix xvi)
- Copies of the Pulley Angle Inquiry Handouts (Appendix xxi)
- OPTIONAL: Copies of the Spring Scale probe handout (Appendix xxi) and copies of the Extend Handout (Appendix xxi)

Teaching Tip:
Give the students a chance to experiment with the protractor first. Be sure that students know how to line up the corner of their protractor with the edge of the pulley and the top of the pulley as shown. Set up a pulley system at the front of the class and have each group come up and measure the angle, then compare results to ensure that all groups understand how to measure the angle.
Lesson 8 continued: Does the angle that you pull the pulley rope change the amount of force?

EVALUATE

How are a pulley and a wheel similar? How are they different? Does a pulley change the amount of force needed to move an object?

Teacher guide for student responses: Both are simple machines, both feature something round, and both make work easier. However, a wheel makes work easier by reducing friction and it rolls on the ground. A pulley requires a rope or string. A pulley makes work easier by changing the direction and/or location of the force you need to lift something, but it does not change the amount of force needed to move an object. With a pulley, you can also lift something higher than your head.

EXTEND (OPTIONAL)

Hand out the Spring Scale Probe (Appendix xxii). Work through Part I of this probe with your students, taking time for them to formulate their answers and have class discussions.

Teacher guide for student responses: Part 1: No work is being done because the weight is not moving. There is a force from gravity but the weight is not moving (no distance).

Have the students work through Part II and answer the first three questions BEFORE you hang the weight from the two spring scales as shown. This is a great opportunity to use the Vote/Discuss/Revote strategy about which student they agree with. Then, make the measurement and discuss with the students. Have them complete Part III.

We can use the ideas from the Spring Scale Probe to see how using more than one pulley can really make our work easier. Diagram A shows the kind of set-up with just 1 pulley. This helps us by allowing us to lift things higher than our heads and by allowing us to change the direction of the force. But look at Diagram B. How is Diagram B similar to the probe we just did? The weight is supported by two ropes, so each rope only carries half of the force. You have to count the number of ropes supporting the weight each time.
Lesson 8 continued: Does the angle that you pull the pulley rope change the amount of force?

A: The weight is supported by one rope; spring scale reading will be the same as the reading just holding the weight
B: Two ropes; the reading in the scale will be half
C: Still two ropes supporting the weight (the third line is not supporting the weight; the reading in the scale will be half
( Maybe only demo these first three?)
D: Three ropes are supporting the weight; the reading will be one third
E: Three ropes are supporting the weight; the reading will be one third


Hand out copies of the Extend Question (Appendix xxiii). After students answer the questions, check their understanding by guiding a discussion.

Force A and Force B are the same because the angle that you pull the rope doesn't change the amount of force. Force C will be half because two strands of rope are supporting the load. Therefore, the correct answer is that Force C < Force A = Force B.
Lesson 9: How can we choose the best simple machine for the job?

**LEARNING TARGETS**
Describe how different simple machines could be used to accomplish similar work.

**SUMMARY**
Students will read a book about a child’s fort designed with many simple machines. They will then work together to design their own secret hide-away.

**ENGAGE**
You should now be able to classify every card in our Simple Machines Card deck. Are there any that we need to discuss or machines that fit into more than one category?

Put the students into six groups. Hand out the Simple Machine Cards so that each group gets seven cards. Have them classify each card and prepare to defend their choices. Do any of the cards have more than one simple machine shown? If so, identify those as well! Use the answer key in Appendix iv-v to check student work.

**EXPLORE**
Give each group a copy of the book and some graph paper. Have them take turns reading a set of pages.

**EXPLAIN**
Answer the questions on the Active Reading handout (Appendix xxiv).
Be creative! Try to find as many ideas as you can for other simple machines (or combinations of simple machines) that could do the same job. You can make sketches on the back of your paper or on blank paper to go with your explanation.

**ELABORATE**
Hands On: Building a Fort
In your group, work together to design your own fort, hide-out or secret clubhouse. It can be anywhere you would like it to be (in a tree, underground, under water, in space, etc). What simple machines can you include? Use the questions in the top part of the Hands On: Building a Fort page to guide your work. Prepare a presentation with drawings to explain your hide-out to the class.

**MYSCI MATERIALS:**
Simple Machine Cards from Lesson 1
6 copies of The Fort on Fourth Street: A Story About the Six Simple Machines by Lois Spangler
Graph paper

**TEACHER PROVIDES:**
Copies of the Questions for Active Reading & Inquiry Questions (Appendix xxiv)
OPTIONAL: Materials to build models of their own fort designs

**Teaching Tip:**
If you arrange the cards by number and hand out 7 cards to each group in order (that is, Group 1 gets Cards 1 - 7, Group 2 gets Cards 8 - 14, etc), this will ensure that each group has a good variety of cards.

**Teaching Tip:**
You can choose to go over student responses after every group finishes the “Explain” portion or allow groups to move on to “Elaborate” and go over both sections together after the “Elaborate” portion.
Lesson 9 continued: How can we choose the best simple machine for the job?

EVALUATE

Simple machines are quite old! They were even used to build the Great Pyramids in Egypt. Show this picture for scale: http://en.wikipedia.org/wiki/Mathematics_and_art#/media/File:Kheops-Pyramid.jpg

Be sure to point out how small the people are compared to each stone block.

✓ Draw a diagram and describe how you might use one of the simple machines to help build the Pyramids. How could the simple machines help you build such a massive structure? Describe how you will use it and how it will make the work easier.

(Optional): Can you figure out a way to use more than one simple machine? How does each one make the work of building the Pyramids easier?

✓ Evaluate student work based on their explanations of how work will be easier and on how many of the simple machines they used. After assessing individual student work, have students share out to the class how they used each simple machine. Were some simple machines harder to find uses for than others?

EXTEND (OPTIONAL)

If you would like to extend this lesson, students can build models of their plans using the materials provided in the kit and additional materials (cardboard, etc) that you supply.
Lesson 10: How do engineers combine simple machines to create amazing and complex creations?

LEARNING TARGETS
Identify simple machines that combine to make up a compound machine.
Design and describe a new compound machine.

SUMMARY
Students will learn about compound machines and create, test, and refine a compound machine of their own using the engineering design process.

ENGAGE
Now that we’ve learned about all of the simple machines, we’re going to reread Papa’s Mechanical Fish. Look for examples of all six simple machines as we read the book. We are going to see which group can identify the most simple machines in the book.

For this part, decide if students will work individually, in pairs or in groups. Read the story again. They should take notes about the simple machines they see and how each one is used. You may want to stop after a few pages and check in with each group to make sure that they are spotting all of the simple machines in the book. After you are finished, go around the room, having them name or explain their simple machine. Others should check that machine off of their list. Go around the room until all of the simple machines have been named and discussed.

EXPLORE
After reading the book to the class, hand out the Listening Passage handout (Appendix xxv) and prepare students to listen as you read the page at the end of the book called “It’s Almost True.”

Then, watch the video below:


Now, the students have three versions of the story to compare/contrast: The picture book, the biographical page and the video clip. Which one is most scientific? Which one is most interesting? Are they all equally true?

EXPLAIN
What does it take to design and build a machine as complex as a submarine? Does it usually work the first time?

Hand out copies of the Engineering Design Cycle (Appendix xxvi) and ask students to review the steps. How is it different and how is it similar to the Scientific Method? Does the design cycle reflect how Lodner Phillips did his work with submarines? Explain how.

ELABORATE
Now, you will get a chance to design a compound machine just like Lodner

MYSCI MATERIALS:
Papa’s Mechanical Fish, by Candace Fleming from Lesson 3
All simple machine materials from previous lessons

TEACHER PROVIDES:
Internet Access
Copies of the Listening Passage handout (Appendix xxv)
Copies of the Engineering Design cycle (Appendix xxvi)
Copies of the Project Rubric (Appendix xxvii)
Additional items for compound machine construction

Teaching Tip:
As mentioned in Lesson 3, this book does not have page numbers, but you could number post-it notes and place them on each page. This will make it easier for students to identify where they see each simple machine. They could set up a simple table:

<table>
<thead>
<tr>
<th>Page</th>
<th>Which Simple Machine?</th>
<th>How is it used?</th>
</tr>
</thead>
</table>

Teaching Tip:
Additional items can include any random materials that you have in your classroom, cleaned recyclables, paper towel tubes, string, etc. You can also ask students to brainstorm and bring items from home.
Lesson 10 continued: *How do engineers combine simple machines to create amazing and complex creations?*

Phillips. Your mission is to create a compound machine that uses at least two of the simple machines to perform a task. This type of machine is sometimes called a “chain reaction” machine or “Rube Goldberg” machine.

Six Simple Machine Projects Using All Six Machines: https://www.youtube.com/watch?v=VunNpfdw68g

Rube Goldberg Project with Six Simple Machines: https://www.youtube.com/watch?v=LMtYSr_abLg

Your task is to make a compound machine that uses at least two different simple machines to perform a task (See Teaching Tip). You can only start the first simple machine. You cannot touch the machine once it is started! Hand out and discuss the project rubric (Appendix xxvii). Put students into six groups and ask them to plan, discuss and sketch. Do not give them the materials until they have some ideas on paper!

EVALUATE

- Have students review the rubric after presentations are done and do a self-evaluation. Then, conference with each team to share your own evaluations. (During team conferences, other students could be doing one of the optional “Extend” items below.)

Audri’s Rube Goldberg Monster Trap: https://www.youtube.com/watch?v=0uDDEEHDf1Y

Our Fifth Grade Compound Machine Project: https://www.youtube.com/watch?v=qwE_BtNbq54

EXTEND (OPTIONAL)

Here are some ideas to extend this lesson with additional writing prompts:

- Compare and contrast your team’s machine with another team’s machine. Find at least two similarities and two differences.

- Provide a step-by-step instruction list on how to build and operate your machine. Include a list of tools and materials that someone would need to create your machine.

Teaching Tip:

Some task ideas for their compound machine include: make a loud noise, pop a balloon with a pin or make a set of 5 dominoes fall down.
### NEXT GENERATION SCIENCE STANDARDS

**Key to Understanding the NGSS Codes**

**NGSS codes begin with the grade level, then the “Disciplinary Core Idea code”, then a standard number. The Disciplinary Core Ideas are:**

**Physical Sciences**
- PS1: Matter and its interactions
- PS2: Motion and stability: Forces and interactions
- PS3: Energy
- PS4: Waves and their applications in technologies for information transfer

**Life Sciences**
- LS1: From molecules to organisms: Structures and processes
- LS2: Ecosystems: Interactions, energy, and dynamics
- LS3: Heredity: Inheritance and variation of traits
- LS4: Biological evolution: Unity and diversity

**Earth and Space Sciences**
- ESS1: Earth’s place in the universe
- ESS2: Earth’s systems
- ESS3: Earth and human activity

**Engineering, Technology, and Applications of Science**
- ETS1: Engineering design
- ETS2: Links among engineering, technology, science, and society

For more information, see WEB LINK

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### NGSS PERFORMANCE EXPECTATIONS

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-5-ETS1-1</td>
<td>Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.</td>
</tr>
<tr>
<td>3-5-ETS1-2</td>
<td>Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.</td>
</tr>
<tr>
<td>3-5-ETS1-3</td>
<td>Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.</td>
</tr>
</tbody>
</table>
**SCIENCE AND ENGINEERING PRACTICES**

**Asking Questions and Defining Problems**
- Ask questions about what would happen if a variable is changed.
- Identify scientific (testable) and non-scientific (non-testable) questions.
- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
- Use prior knowledge to describe problems that can be solved.
- Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

**Developing and Using Models**
- Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.
- Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.

**Planning and Carrying Out Investigations**
- Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
- Evaluate appropriate methods and/or tools for collecting data.
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
- Make predictions about what would happen if a variable changes.
- Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success.

**Analyzing and Interpreting Data**
- Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.
- Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.
- Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
- Analyze data to refine a problem statement or the design of a proposed object, tool, or process.
- Use data to evaluate and refine design solutions.

**Using Mathematics and Computational Thinking**
- Organize simple data sets to reveal patterns that suggest relationships.
- Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.

**Constructing Explanations and Designing Solutions**
- Construct an explanation of observed relationships (e.g., the distribution of plants in the back yard).
- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
- Identify the evidence that supports particular points in an explanation.
- Apply scientific ideas to solve design problems.
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.

**Engaging in Argument from Evidence**
- Compare and refine arguments based on an evaluation of the evidence presented.
- Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.
- Construct and/or support an argument with evidence, data, and/or a model.
- Use data to evaluate claims about cause and effect.
- Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.

**Obtaining, Evaluating and Communication Information**
- Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence.
- Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific and/or engineering practices.
- Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.
- Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.

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**CROSSCUTTING CONCEPTS**

**Patterns**
- Patterns of change can be used to make predictions.
- Patterns can be used as evidence to support an explanation.

**Cause and Effect: Mechanism and Prediction**
- Cause and effect relationships are routinely identified, tested, and used to explain change.

**Scale, Proportion, and Quantity**
- Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.

**Systems and System Models**
- A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.
- A system can be described in terms of its components and their interactions.

**Structure and Function**
- Substructures have shapes and parts that serve functions.

**Stability and Change**
- Change is measured in terms of differences over time and may occur at different rates.
MISSOURI GLE STANDARDS

Key to Understanding the GLE Codes

GLE codes are a mixture of numbers and letters, in this order: Strand, Big Idea, Concept, Grade Level and GLE Code.

The most important is the strand. The strands are:

1. **ME**: Properties and Principles of Matter and Energy
2. **FM**: Properties and Principles of Force and Motion
3. **LO**: Characteristics and Interactions of Living Organisms
4. **EC**: Changes in Ecosystems and Interactions of Organisms with their Environments
5. **ES**: Processes and Interactions of the Earth's Systems (Geosphere, Atmosphere and Hydrosphere)
6. **UN**: Composition and Structure of the Universe and the Motion of the Objects Within It
7. **IN**: Scientific Inquiry
8. **ST**: Impact of Science, Technology and Human Activity

For more information see web link.

### GLE Standards

<table>
<thead>
<tr>
<th>FM 2 F 2 b</th>
<th>IN 1 B 5 c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compare and describe the amount of force (i.e., more, less, or same push or pull) needed to raise an object to a given height, with or without using levers</td>
<td>Use a variety of tools and equipment to gather data (e.g., hand lenses, magnets, thermometers, metric rulers, balances, graduated cylinders, spring scales)</td>
</tr>
<tr>
<td>FM 2 F 2 c</td>
<td>IN 1 B 5 d</td>
</tr>
<tr>
<td>Apply the use of an inclined plane (ramp) and/or lever to different real life situations in which objects are raised</td>
<td>Measure length to the nearest centimeter, mass to the nearest gram, volume to the nearest milliliter, temperature to the nearest degree Celsius, force/weight to the nearest Newton</td>
</tr>
<tr>
<td>FM 2 A 4 d</td>
<td>IN 1 B 5 e</td>
</tr>
<tr>
<td>Compare the forces (measured by a spring scale in Newton’s) required to overcome friction when an object moves over different surfaces (i.e., rough/smooth)</td>
<td>Compare amounts/measurements</td>
</tr>
<tr>
<td>FM 2 B 4 a</td>
<td>IN 1 B 5 f</td>
</tr>
<tr>
<td>Determine the gravitational pull of the Earth on an object (weight) using a spring scale</td>
<td>Judge whether measurements and computation of quantities are reasonable</td>
</tr>
<tr>
<td>FM 2 D 4 a</td>
<td>IN 1 C 5 a</td>
</tr>
<tr>
<td>Observe that balanced forces do not affect an object’s motion</td>
<td>Use quantitative and qualitative data as support for reasonable explanations</td>
</tr>
<tr>
<td>FM 2 A 5 a</td>
<td>IN 1 C 5 b</td>
</tr>
<tr>
<td>Identify the forces acting on a load and use a spring scale to measure the weight (resistance force) of the load</td>
<td>Use data as support for observed patterns and relationships, and to make predictions to be tested</td>
</tr>
<tr>
<td>FM 2 D 5 a</td>
<td>IN 1 C 5 c</td>
</tr>
<tr>
<td>Describe how friction affects the amount of force needed to do work over different surfaces or through different media</td>
<td>Evaluate the reasonableness of an explanation</td>
</tr>
<tr>
<td>FM 2 F 5 a</td>
<td>IN 1 C 5 d</td>
</tr>
<tr>
<td>Explain how work can be done on an object (force applied and distance moved)</td>
<td>Analyze whether evidence supports proposed explanations</td>
</tr>
<tr>
<td>FM 2 F 5 b</td>
<td>IN 1 D 5 a</td>
</tr>
<tr>
<td>Identify the simple machines in common tools and household items</td>
<td>Communicate the procedures and results of investigations and explanations through oral presentations, drawings and maps, data tables, graphs (bar, single line, pictograph), writings</td>
</tr>
<tr>
<td>FM 2 F 5 c</td>
<td>ST 1 A 5 a</td>
</tr>
<tr>
<td>Compare the measures of effort force (measured using a spring scale to the nearest Newton) needed to lift a load with and without the use of simple machines</td>
<td>Design and construct a machine, using materials and/or existing objects, that can be used to perform a task</td>
</tr>
<tr>
<td>FM 2 F 5 d</td>
<td>ST 1 C 5 a</td>
</tr>
<tr>
<td>Observe and explain simple machines change the amount of effort force and/or direction of force</td>
<td>Identify how the effects of inventions or technological advances (e.g., complex machinery, technologies used in space exploration, satellite imagery, weather observations and prediction, communication, transportation, robotics, tracking devices) may be helpful, harmful, or both</td>
</tr>
<tr>
<td>IN 1 A 5 a</td>
<td>ST 2 A 5 a</td>
</tr>
<tr>
<td>Formulate testable questions and explanations (hypotheses)</td>
<td>Research biographical information about various scientists and inventors from different gender and ethnic backgrounds, and describe how their work contributed to science and technology</td>
</tr>
<tr>
<td>IN 1 A 5 b</td>
<td>ST 3 A 5 a</td>
</tr>
<tr>
<td>Recognize the characteristics of a fair and unbiased test</td>
<td>Identify a question that was asked, or could be asked, or a problem that needed to be solved when given a brief scenario (fiction or nonfiction of people working alone or in groups solving everyday problems or learning through discovery)</td>
</tr>
<tr>
<td>IN 1 A 5 c</td>
<td>ST 3 A 5 b</td>
</tr>
<tr>
<td>Conduct a fair test to answer a question</td>
<td>Work with a group to solve a problem, giving due credit to the ideas and contributions of each group member</td>
</tr>
<tr>
<td>IN 1 A 5 d</td>
<td></td>
</tr>
</tbody>
</table>
# Work Scenarios Handout

## Lesson 1, Section 1

Name: ____________________________  Date: _______________

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>WHAT IS THE SAME (CONTROL VARIABLE)?</th>
<th>WHAT DID WE CHANGE (INDEPENDENT VARIABLE)?</th>
<th>HOW DID THIS AFFECT WORK (DEPENDENT VARIABLE)? WHO DID MORE WORK?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<tr>
<td>9</td>
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</tr>
</tbody>
</table>

**EVALUATE: SUMMARY AND CONCLUSION**

1. How do you know if work is being done or not?

2. How do you compare the amount of work being done? What two variables do you have to look at?
EVALUATE: SUMMARY AND CONCLUSION

1. How do you know if work is being done or not?
   
   *If the object moves from a starting location to a final location (displacement), work is being done. Work is done by the person applying the force, by gravity, or by other forces.*

2. How do you compare the amount of work being done? What two variables do you have to look at?
   
   *You have to know what force is being used and how far the object moves from start to finish.*
Extend Questions

Section 1, Lesson 1

1. Your teacher asks two students to carry identical books to the back of the room. Student A walks straight to the back of the room at a slow pace. Student B runs back and forth across the room with the book, eventually reaching the back of the room. Which student did more work?

2. Your teacher asks two students to carry identical books from the front of the room to the back. The first student takes the book and walks to the back of the room and puts it on the shelf, then walks to the front of the room empty handed. The second student takes the book and walks to the back of the room and then returns to the front of the room with the book. Who did more work?

Discussion Notes:
# Simple Machine Cards Answer Key

## Lessons 1, 3, 6 & 10

<table>
<thead>
<tr>
<th>#</th>
<th>DESCRIPTION</th>
<th>MACHINE TYPE</th>
<th>TEACHER NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bicycle pedals</td>
<td>Lever (Class 1)</td>
<td>Students may identify the wheel and axel but guide them to look at the pedal part as a lever.</td>
</tr>
<tr>
<td>2</td>
<td>Chopsticks</td>
<td>Lever (Class 3)</td>
<td>It is two class 3 levers</td>
</tr>
<tr>
<td>3</td>
<td>Parking Garage Ramp</td>
<td>Screw</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rolling suitcase (wheel)</td>
<td>Wheel and Axel</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rolling suitcase (whole thing)</td>
<td>Lever (Class 2)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sail (pulley part)</td>
<td>Pulley</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Wheelchair ramp</td>
<td>Inclined Plane</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Boat oar</td>
<td>Lever (Class 1)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Broom</td>
<td>Lever (Class 3)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Flag pole (pulley part)</td>
<td>Pulley</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Ladder</td>
<td>Inclined Plane</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Paper cutter</td>
<td>Lever (Class 2)</td>
<td>The blade might also be either a wedge or an inclined plane</td>
</tr>
<tr>
<td>13</td>
<td>Pizza cutter (the wheel part)</td>
<td>Wheel and Axel</td>
<td>The blade might also be either a wedge or an inclined plane</td>
</tr>
<tr>
<td>14</td>
<td>Twisty slide</td>
<td>Screw</td>
<td>The ladder of the slide is also an inclined plane</td>
</tr>
<tr>
<td>15</td>
<td>Baseball bat</td>
<td>Lever (Class 3)</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Bucket and Well</td>
<td>Pulley</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Door (hinge)</td>
<td>Lever (Class 2)</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Merry Go Round</td>
<td>Wheel and Axel</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Pushpin (the pointy part)</td>
<td>Wedge</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Simple catapult</td>
<td>Lever (Class 1)</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Staircase</td>
<td>Inclined Plane</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Wheelbarrow (lever part)</td>
<td>Lever (Class 2)</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Crane (pulley part on the end)</td>
<td>Pulley</td>
<td>The arm of the crane is a lever</td>
</tr>
<tr>
<td>24</td>
<td>Crowbar</td>
<td>Lever (Class 1)</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Door stop</td>
<td>Wedge</td>
<td>If students are confused as to why this is not an inclined plane, explain that the wedge is using both of its sides to “push apart” the door and the floor.</td>
</tr>
<tr>
<td>26</td>
<td>Fishing Pole</td>
<td>Lever (Class 3)</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Sliding board</td>
<td>Inclined Plane</td>
<td>The slide part AND the ladder part are both inclined planes</td>
</tr>
</tbody>
</table>
# Simple Machine Cards Answer Key

**Lessons 1, 3, 6 & 10 (continued)**

<table>
<thead>
<tr>
<th>#</th>
<th>DESCRIPTION</th>
<th>MACHINE TYPE</th>
<th>TEACHER NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Wheelbarrow (wheel part)</td>
<td>Wheel and Axel</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Bathtub (whole tub)</td>
<td>Inclined Plane</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Axe (just the axe head part)</td>
<td>Wedge</td>
<td>The whole axe also acts as a lever</td>
</tr>
<tr>
<td>31</td>
<td>Door knob</td>
<td>Wheel and Axel</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Hockey Stick</td>
<td>Lever (Class 3)</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Jar lid</td>
<td>Screw</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Nutcracker</td>
<td>Lever (Class 2)</td>
<td>It is two class 2 levers</td>
</tr>
<tr>
<td>35</td>
<td>Seesaw</td>
<td>Lever (Class 1)</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Bicycle (Wheels)</td>
<td>Wheel and Axel</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Drill</td>
<td>Screw</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Scissors (blades)</td>
<td>Wedge</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Scissors (mechanism)</td>
<td>Lever (Class 1)</td>
<td>It is two class 1 levers</td>
</tr>
<tr>
<td>40</td>
<td>Sewing Needle (the point)</td>
<td>Wedge</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Rake</td>
<td>Lever (Class 3)</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Shovel</td>
<td>Lever (Class 1)</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Rolling Pin</td>
<td>Wheel and Axel</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Hammer</td>
<td>Lever</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Boat Rudder</td>
<td>Lever (Class 1)</td>
<td>Use as demo card in Lesson 1</td>
</tr>
</tbody>
</table>

**LESSON 3:**
Levers (Class 1): 1, 8, 20, 24, 35, 39, 42  
Levers (Class 2): 5, 12, 16, 22, 34  
Levers (Class 3): 2, 9, 15, 26, 32  

**LESSON 6:**
Inclined Planes: 7, 11, 21, 27, 29  
Wedges: 19, 25, 30, 38, 40  
Screws: 3, 14, 33, 37  

**LESSON 10:**
Wheels 4, 13, 18, 28, 31, 36, 43  
Pulley: 6, 10, 17, 23
**Independent and Dependent Variable Worksheet**

**Section 1, Lesson 2**

Identify the dependent variable and the independent variable and some control variables.

Example: Mavis owns an ice cream shop. Every day she records how much ice cream she sells and the high temperature for the day.

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>DEPENDENT VARIABLE</th>
<th>CONTROL VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

**QUESTION 1:** Mitchell is playing golf. He notices that all of the golf balls look the same, but some of them are heavier than others. He wonders if this will make them travel different distances.

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>DEPENDENT VARIABLE</th>
<th>CONTROL VARIABLES</th>
</tr>
</thead>
<tbody>
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</table>

**QUESTION 2:** Merrill loves to blow bubbles with her chewing gum. She wants to know what kind of gum will allow her to make the largest bubbles.

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>DEPENDENT VARIABLE</th>
<th>CONTROL VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Independent and Dependent Variable Worksheet Answer Key

Section 1, Lesson 2

Identify the dependent variable and the independent variable and some control variables.

Example: Mavis owns an ice cream shop. Every day she records how much ice cream she sells and the high temperature for the day.

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>DEPENDENT VARIABLE</th>
<th>CONTROL VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Temperature is the independent variable because it changes from day to day with the weather.</td>
<td>How much ice cream she sells. This depends on the temperature because when it is hotter outside, more people want ice cream. Higher temperature makes sales go up. It doesn’t make sense to say we sell more ice cream and that makes it get hotter or colder out!</td>
<td>The ice cream shop is in the same location. The ice cream is the same every day (no new or special flavors).</td>
</tr>
</tbody>
</table>

QUESTION 1: Mitchell is playing golf. He notices that all of the golf balls look the same, but some of them are heavier than others. He wonders if this will make them travel different distances.

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>DEPENDENT VARIABLE</th>
<th>CONTROL VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>The independent variable is how much each golf ball weighs</td>
<td>The dependent variable is how far each golf ball will go after he hits it.</td>
<td>The control variables are that he uses the same golf club, swings the golf club with the same force each time. Additional control variables could be that the weather is the same the whole time, including the wind speed and direction.</td>
</tr>
</tbody>
</table>

QUESTION 2: Merrill loves to blow bubbles with her chewing gum. She wants to know what kind of gum will allow her to make the largest bubbles.

<table>
<thead>
<tr>
<th>INDEPENDENT VARIABLE</th>
<th>DEPENDENT VARIABLE</th>
<th>CONTROL VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>The independent variable is the kind of gum that she is chewing (different brands and flavors).</td>
<td>The dependent variable is the size of the bubbles.</td>
<td>The control variables include chewing the gum the same number of times, using the same amount of gum, and the fact that it is the same person chewing the gum.</td>
</tr>
</tbody>
</table>
Spring Scales and Balance

Section 1, Lesson 2

GUIDING QUESTIONS AND PREDICTIONS:
1. How much force will it take to balance the load?

2. How does the position of a load affect the force to balance the load?

Label these items on the drawing:
- Spring Scale
- Lever
- Fulcrum
- Weight

INDEPENDENT VARIABLE (YOU CHANGE IT)
DEPENDENT VARIABLE (MEASURE THE RESULT)
CONTROL VARIABLES (STAYS THE SAME)
The **distance** between the fulcrum and the weight, measured with the tape measure.
The **force** on the required to balance the weight, measure it with the spring scale.
1. Use the same weight
2. Keep the same distance between the spring scale and the fulcrum
### Spring Scales and Balance (continued)

**Section 1, Lesson 2**

**Title:**

<table>
<thead>
<tr>
<th>DEPENDENT VARIABLE:</th>
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</table>

**INDEPENDENT VARIABLE:** ________________________________

**What is your conclusion and how does it compare with your prediction?**

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Evaluate
Section 1, Lesson 2

EVALUATE

1. In our experiment, what was the independent variable (the thing we changed)? How do you know that this is the independent variable?

2. What was the dependent variable (the thing we measured to see the effect)? How do you know that this is the dependent variable?

3. Name at least two control variables (things that we did not change) in our experiment.

4. How could a small mouse balance a giant elephant on a lever? It is possible! Draw it on the back of this paper and label a sketch that shows how.

BONUS
Archimedes was a Greek mathematician, scientist, and inventor who lived about 2200 years ago. His favorite topics were geometry and simple machines. Archimedes once said: “Give me a lever long enough and a fulcrum on which to place it, and I shall move the world.” Do you agree or disagree with his statement? If you agree, draw a sketch showing Earth, your lever, fulcrum, and force. If you disagree, give a detailed explanation of why you disagree.
Evaluate Answer Key
Section 1, Lesson 2

EVALUATE
1. In our experiment, what was the independent variable (the thing we changed)? How do you know that this is the independent variable?

   The independent variable was the distance between the fulcrum and the weight. I know that this is the independent variable because it is the thing that we changed.

2. What was the dependent variable (the thing we measured to see the effect)? How do you know that this is the dependent variable?

   The dependent variable is the force measured on the spring scale that is needed to balance the load. I know that this is the dependent variable because we measured it to see if it changed.

3. Name at least two control variables (things that we did not change) in our experiment.

   We used the same equipment, same spring scale, same weight, same lever and fulcrum. We also kept the distance between the spring scale and the fulcrum the same.

4. How could a small mouse balance a giant elephant on a lever? It is possible! Draw it on the back of this paper and label a sketch that shows how.

   If the mouse was on the end of the lever VERY FAR from the fulcrum and the elephant was very close to the fulcrum, it could balance. The diagram should show this.

BONUS
Archimedes was a Greek mathematician, scientist, and inventor who lived about 2200 years ago. His favorite topics were geometry and simple machines. Archimedes once said: “Give me a lever long enough and a fulcrum on which to place it, and I shall move the world.” Do you agree or disagree with his statement? If you agree, draw a sketch showing Earth, your lever, fulcrum, and force. If you disagree, give a detailed explanation of why you disagree.

   Archimedes is correct—IF he could find a long enough lever and a fulcrum to place it on. Students who agree should draw a sketch showing the earth, a fulcrum (perhaps another planet or the sun?), and a force attempting to move the earth. The lever should be very long, the fulcrum should be near the earth, and the force (or Archimedes), should be very far away. Students should notice from the experiment that when the weight (in this case, Earth) is near the fulcrum, it requires much less force to balance the weight. Students may disagree by saying that is impossible to get a lever that long or a fulcrum. If so, the teacher should go back to the statement Archimedes made. IF he had a lever long enough and a fulcrum, could it be done?
Evaluate
Section 1, Lesson 3

DIRECTIONS
The crate below is being opened with a lever. Identify the fulcrum, force, and load for this drawing.
NAME(S): ________________________________________________________________

TESTABLE QUESTION
What is the goal or question of this experiment?

________________________________________________________________________
________________________________________________________________________

________________________________________________________________________

VARIABLES
The control variables include ____________________________________________
because ________________________________________________________________
The independent variable is ____________________________________________
because ________________________________________________________________
The dependent variable is ____________________________________________
because ________________________________________________________________

PREDICTION
What do you think will happen?

________________________________________________________________________
________________________________________________________________________

________________________________________________________________________

SKETCH
Show your set-up, labeling the equipment you will use.
## Recording Sheet (continued)

### Section 2, Lesson 4

<table>
<thead>
<tr>
<th>TITLE:</th>
<th>INDEPENDENT VARIABLE:</th>
<th>DEPENDENT VARIABLE:</th>
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<tbody>
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**INDEPENDENT VARIABLE:** __________________________________________

What is your conclusion and how does it compare with your prediction?

____________________________________________________________________

____________________________________________________________________

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____________________________________________________________________
Evaluate
Section 2, Lesson 4

DIRECTIONS
For each comparison, decide if the first force is greater than, less than, or the same as the second force. Then, explain why you are making that claim.

<table>
<thead>
<tr>
<th>First Comparison</th>
<th>Greater Than, Less Than, or Equal To?</th>
<th>Second Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>The force needed to push a crate of 10 science books</td>
<td></td>
<td>The force needed to push a crate of 10 science books</td>
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<tr>
<td>across smooth ice</td>
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<td>across a rough parking lot</td>
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<td>Why?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>First Comparison</th>
<th>Greater Than, Less Than, or Equal To?</th>
<th>Second Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>The force needed to push a crate of 100 science books</td>
<td></td>
<td>The force needed to push a crate of 10 science books</td>
</tr>
<tr>
<td>across a rough parking lot</td>
<td></td>
<td>across a rough parking lot</td>
</tr>
<tr>
<td></td>
<td>Why?</td>
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</table>
Protractor Printable

Section 3, Lessons 5 & 8

**LESSON 5:** Inclined Plane

**LESSON 8:** Pulley
Evaluate
Section 2, Lesson 5

QUESTIONS
Look at this wheelchair ramp. Is this a good ramp design? Why or why not?

How could we change the angle of the ramp to make it a better wheelchair ramp?
Regular Slide vs Spiral Slide

Section 2, Lesson 6

How are the two slides the same? How are they different? Fill out the chart with your ideas.

<table>
<thead>
<tr>
<th>Regular Slide</th>
<th>Both Slides</th>
<th>Spiral Slide</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

1. What kind of simple machine is the regular slide? ________________________________

2. What kind of simple machine is the spiral slide? ________________________________

3. Both the spiral slide and the regular slide do the same kind of work. Describe the work that they do.
   ____________________________________________________________________________

4. Which slide do you think is better? Why?
   ____________________________________________________________________________

   ____________________________________________________________________________
Travois Images

Section 3, Lesson 7

[Diagram of a dog pulling a load with labels for load, effort, and fulcrum]

[Photo of a boy pulling a dog-drawn travois]

Travois Images

Section 3, Lesson 7

[Diagram of a dog pulling a load with labels for load, effort, and fulcrum]

[Photo of a boy pulling a dog-drawn travois]
Extend

Section 3, Lesson 7

**DIRECTIONS**

Have students keep the ramp angle constant and then test each of the conditions described in this table.

<table>
<thead>
<tr>
<th>Force Needed to Pull Car Up a ramp, angle</th>
<th>No Weight in Car</th>
<th>Weight in Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car on its Wheels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car on its Roof</td>
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</tbody>
</table>
Pulley Angle Inquiry
Section 3, Lesson 8

PART I
The teacher hangs a mass on the spring scale. Read the force, and record it here: __________________________
If we attach the mass to a single pulley, what force will be required on the spring scale to lift the mass?
Record prediction here: __________________________
Record measured value here: __________________________
Did your prediction match your result? __________________________

PART II
How does the angle that you pull the string affect the amount of force required? (Choose one):
A. Increasing the angle of the string will decrease the amount of force required to lift the object. The force measured on the spring scale will be LESS than the force needed when the rope is straight down.
B. The angle of the string does not affect the amount of force required to lift the object. The force will be the same even if the angle changes.
C. Increasing the angle of the string will increase the amount of force required to lift the object. The force measured on the spring scale will be MORE than the force needed when the rope is straight down.

PART III
Planning your investigation. How will you investigate your claim from Part II?
What will you set up?
What will you measure and record? What is the independent variable and what is the dependent variable? How will you make sure that you have a fair test (what is held constant)?
How will you present your data? What will your graph look like?
Spring Scale Probe (Optional)

Section 3, Lesson 8

PART I
Hang a mass on the spring scale. Read the force, and record it here: ________

When the object is hanging from the scale, is work being done? If so, who or what is doing the work? If not, why not?

HYPOTHESIS: Five students came up with different hypotheses. Which one do you agree with?

A. Aaron’s hypothesis is that each spring scale will read the same force as the single spring scale in Part I.
B. Belinda’s hypothesis is that each spring scale will read a little bit more force than the single spring scale in Part I.
C. Celine’s hypothesis is that each spring scale will read a little bit less force than the single spring scale in Part I.
D. Devon’s hypothesis is that each spring scale will read half of the force of the single scale in Part I.
E. Elijah’s hypothesis is that each spring scale will read twice the force of the spring scale in Part I.

Read the force, and record it here: ____________________________

PART II
Next, the teacher is going to set up a new experiment using the same mass. The weight will be held by two spring scales using a string, as shown here:

What is the same as Part I?

What is different?

HYPOTHESIS: Five students came up with different hypotheses. Which one do you agree with?

A. Aaron’s hypothesis is that each spring scale will read the same force as the single spring scale in Part I.
B. Belinda’s hypothesis is that each spring scale will read a little bit more force than the single spring scale in Part I.
C. Celine’s hypothesis is that each spring scale will read a little bit less force than the single spring scale in Part I.
D. Devon’s hypothesis is that each spring scale will read half of the force of the single scale in Part I.
E. Elijah’s hypothesis is that each spring scale will read twice the force of the spring scale in Part I.

Read the force, and record it here: ____________________________

PART III
Whose hypothesis was correct?

What would be the reading on each spring scale if there were 3 spring scales holding the mass? Why?
Section 3, Lesson 8

DIRECTIONS

Each of these three people is trying to use a pulley and ropes to lift the same sized load. Put them in order from lowest force to highest force.

Force A Ranking: ________________________________
Why? ________________________________________
____________________________________________
____________________________________________
____________________________________________
____________________________________________

Force B Ranking: ________________________________
Why? ________________________________________
____________________________________________
____________________________________________
____________________________________________
____________________________________________

Force C Ranking: ________________________________
Why? ________________________________________
____________________________________________
____________________________________________
____________________________________________
____________________________________________
### Active Reading & Inquiry Questions

#### Section 4, Lesson 9

**DIRECTIONS**

Read the *Fort on Fourth Street: A Story About the Six Simple Machines* by Lois Spangler. As you read through the book, identify each simple machine, the job it does, and how it makes work easier. For each simple machine you find, could any other simple machine do the same job? If so, describe how.

<table>
<thead>
<tr>
<th>SIMPLE MACHINE</th>
<th>THE JOB IT DOES</th>
<th>HOW DOES IT MAKE WORK EASIER?</th>
<th>COULD ANOTHER SIMPLE MACHINE DO THE JOB? IF SO, HOW?</th>
</tr>
</thead>
<tbody>
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</table>
DIRECTIONS
As you listen to the reading passage and think about the book, Papa’s Mechanical Fish, answer the following questions:

What do you think was the author’s purpose in writing two versions of the same story? Why was one version of the story not enough?

2. What are some details in the non-fiction story book that you think are not true. Why do you think that?
Engineering Design Cycle

Section 4, Lesson 10

1. Identify Need/Problem

2. Research & Brainstorm

3. Choose Best Ideas

4. Construct Prototype

5. Test & Evaluate

6. Communicate

7. Redesign
# Project Rubric

## Section 4, Lesson 10

<table>
<thead>
<tr>
<th>NOT MEETING (1)</th>
<th>APPROACHING (2)</th>
<th>MEETING (3)</th>
<th>EXCEEDING (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Rules</strong></td>
<td>Our machine does not contain at least 2 simple machines and does not work on its own.</td>
<td>Our machine contains at least 2 simple machines but does not work on its own.</td>
<td>Our machine contains at least 2 different simple machines and works by touching only the first simple machine (chain reaction).</td>
</tr>
<tr>
<td><strong>Sketch</strong></td>
<td>Our sketch is does not have labels and it is not possible to see how machine works using only the sketch.</td>
<td>Our sketch gives a general idea of our machine, but more explanation would be required for someone to build our machine using only the sketch.</td>
<td>Our sketch is neat and clearly shows the simple machines. The sketch has labels. Someone could build our machine using only the sketch.</td>
</tr>
<tr>
<td><strong>Presentation</strong></td>
<td>Our presentation was confusing and didn’t clearly explain our machine or our design process. Couldn’t be heard or understood.</td>
<td>Our presentation explained our machine and design process, but more information was needed to clearly understand them both.</td>
<td>Our presentation clearly explained our machine and the design process that we went through to create the machine.</td>
</tr>
<tr>
<td><strong>Teamwork and Communication</strong></td>
<td>Our team did not work well together, with disagreements, off-task behavior, and unequal work amounts.</td>
<td>Our team was usually on-task and peaceful, with everyone contributing some work, but we had a couple of small issues with teamwork.</td>
<td>All of our team members contributed equally to the work and worked peacefully together at all times.</td>
</tr>
</tbody>
</table>

### SELF ASSESSMENT SCORE AND COMMENTS

<table>
<thead>
<tr>
<th>Design Rules</th>
<th>Sketch</th>
<th>Presentation</th>
<th>Teamwork and Communication</th>
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</thead>
<tbody>
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### TEACHER ASSESSMENT SCORE AND COMMENTS

<table>
<thead>
<tr>
<th>Design Rules</th>
<th>Sketch</th>
<th>Presentation</th>
<th>Teamwork and Communication</th>
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### TOTAL

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Vocabulary & Glossary
All Sections and Lessons

RECOMMENDATION
We recommend that students participate in investigations as they learn vocabulary, that it is introduced as they come across the concept. MySci students work collaboratively and interact with others about science content also increasing vocabulary. The hands-on activities offer students written, oral, graphic, and kinesthetic opportunities to use scientific vocabulary and should not be taught in isolation.

FORCE
A force is a push or pull upon an object resulting from the object’s interaction with another object. Whenever there is an interaction between two objects, there is a force upon each of the objects. When the interaction ceases, the two objects no longer experience the force. Forces only exist as a result of an interaction.

LOAD
The object being moved. The amount of work being done by a person or machine.

WORK
W=FxD; Work is done if a force moves an object a distance.

DISTANCE
A measure of how far an object moves. Measured using the metric system.

DISPLACEMENT
The distance between the starting point and the ending point of motion.

FAIR TEST
When using the scientific process your testing conditions are held constant (the same). Only one thing can change and we measure the impact of the change. The test should be tried at least three times.

CONTROL VARIABLES
The variables that stay the same throughout the entire experiment. You “control” these by keeping them the same. These can also be called “constant variables” or “controlled variables.”

INDEPENDENT VARIABLE
This is the variable that is changed.

DEPENDENT VARIABLE
This variable depends on the independent variable. It changes based on what we did to the independent variable. This is what we observe and or measure.

FRICION
A force caused by objects rubbing.

LEVER
A straight rod or board that pivots on a point (fulcrum). The fulcrum can be moved depending on the weight of the object to be lifted or the force you wish to exert. Pushing down on one end of a lever results in the upward motion of the opposite end of the fulcrum.

FULCRUM
A point that a rod or board pivots around in a lever.

INCLINED PLANE
A flat surface with one end higher than the other. A ramp is an inclined plane.

WEDGE
A simple machine with inclined planes. A wedge changes the direction of a force.

SCREW
A simple machine with an inclined plane wrapped around a center post. A screw changes the direction of the force as you turn.

WHEEL
A simple machine that is a circular object that turns around a center point (axis).

AXEL
A shaft inserted into the center of a wheel.

PULLEY
A wheel that usually has a groove around the outside edge. This groove is for a rope or belt to move around the pulley. Pulling down on the rope can lift an object attached to the rope.

COMPOUND
Two or more simple machines working together.

ENGINEER
A person who designs, builds, or maintains engines, machines, or public works.

GRAVITY
The force that pulls an object towards the center of the Earth.