

Science through LEGO Engineering **Design a People Mover: Simple Machines**

Curriculum Resources
2008-2009 Edition

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LEGO® engineering

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Section 1: Teacher's Guide

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Module Overview

Simple Machines: Design a People Mover

Lesson Title	Lesson Overview	Lesson Learning Objectives <i>Students will be able to:</i>
1: What machines help people move?	Students will be introduced to the design challenge of building people movers, machines that move people <i>up</i> and <i>over</i> . They will consider the pluses and minuses (trade-offs) of these machines.	<i>Define engineering design as the process of creating solutions to human problems.</i>
2: What are the seven simple machines?	Students will be introduced to the term ‘machines’ and to the seven simple machines.	<i>Explain that simple machines help humans</i> <i>Define engineering design as the process of creating solutions to human problems through creativity and the application of math and science knowledge.</i>
3: What happens when we change a lever’s rotation point?	Students will be introduced to the mechanics of levers and the ways levers can help humans. Students will be introduced to key lever vocabulary (load, force, distance, rotation point) through demonstrations of a prying lever and investigating weight-lifting levers.	<i>Explain that levers, which are stiff bars that rotate around fixed points, make it easier to lift a load or apply a force.</i>
4: What are other types of levers?	Students will discuss how a lever’s rotation point affects the applied force and distance, as well as be introduced to the mechanics of two-armed levers and the ways they can help humans. Students will also identify everyday examples of levers.	<i>Explain that levers, which are stiff bars that rotate around fixed points, make it easier to lift a load or apply a force.</i> <i>Identify examples of simple machines (levers) in everyday objects.</i> <i>Identify simple machines (levers) within complex machines.</i>
5: How do wheel-and-axle systems work?	Students will test wheels of different shapes and lengths to determine which requires the least effort to turn a model food mixer.	<i>Explain that wheel-and-axles, which are two differently-sized wheels attached to the same axis, are used to make circular motion easier.</i> <i>Identify examples of simple machines (wheel-and-axles) in everyday objects.</i> <i>Identify simple machines (wheel-and-axles) within complex machines.</i>

Module Overview

Simple Machines: Design a People Mover

Lesson Title	Lesson Overview	Lesson Learning Objectives <i>Students will be able to:</i>
<p>6: How do inclined planes, screws, and wedges work?</p>	<p>Students will be introduced to the uses of inclined planes, screws, and wedges and the ways inclined planes, screws and wedges can help humans. Students will test inclined planes of varying lengths to determine which require the least force. Students will also find the inclined planes in wedges and screws.</p>	<p><i>Explain that inclined planes, which are surfaces slanted upwards, lower the effort needed to lift a load.</i></p> <p><i>Explain that wedges, which are two inclined planes joined back to back to form a sharp edge, are used to change the direction of a force and often result in the splitting of objects.</i></p> <p><i>Explain that screws, which are inclined planes wrapped around a cylinder, are used to raise and lower objects and hold objects together.</i></p> <p><i>Identify examples of simple machines (inclined planes, screws, and wedges) in everyday objects.</i></p> <p><i>Identify simple machines (inclined planes, wedges, screws) within complex machines.</i></p>
<p>7: How do pulleys work?</p>	<p>Students will be introduced to pulley systems as a means for lifting heavy things to heights above our heads. They will explore differently sized pulleys and observe the force and distance of pull with fixed and moveable pulley systems.</p>	<p><i>Explain that pulleys, which are wheels with grooved edges for ropes, are used to change the direction of a pull and make it easier to lift a load.</i></p>
<p>8: How do gears change circular motion?</p>	<p>Students will be introduced to the uses of gears and the ways gears can help humans to change the direction, speed, and force of circular motion. If time permits, students will also build a gear train that will spin a disk fast enough to create an optical illusion.</p>	<p><i>Explain that gears, which are wheels with teeth around the edge, are used to turn other gears and change the direction, speed, and force of circular motion.</i></p>

Module Overview

Simple Machines: Design a People Mover

Lesson Title	Lesson Overview	Lesson Learning Objectives <i>Students will be able to:</i>
<p>9: How can we find simple machines in complex machines?</p>	<p>Students will be introduced to how simple machines can be found inside and put together to make complex machines. Student will review the force-distance trade-offs of simple machines and begin the preliminary design of their people mover.</p>	<p><i>Identify simple machines within complex machines.</i></p> <p><i>Choose appropriate simple machines to solve a mechanical problem.</i></p>
<p>10: What simple machines can be used to create a model people mover?</p>	<p>Students will construct, rate, modify, and diagram their model people mover.</p>	<p><i>Identify simple machines within complex machines.</i></p> <p><i>Choose appropriate simple machines to solve a mechanical problem.</i></p>
<p>11: How do simple machines help us?</p>	<p>Students will present their complex machines to other students and review other students' machines. A culminating class discussion will help students reflect on their learning about simple and complex machines.</p>	<p><i>Identify simple machines within complex machines.</i></p> <p><i>Choose appropriate simple machines to solve a mechanical problem.</i></p>

Learning Objectives for LEGO Engineering
Simple Machines Module

06/26/08

- 1) Explain what the following simple machines do to help humans:
 - a) Levers, which are stiff bars that rotate around fixed points, make it easier to lift a load or apply a force.
 - b) Wheel-and-axles, which are two differently-sized wheels attached to the same axis, are used to make circular motion easier.
 - c) Inclined planes, which are surfaces slanted upwards, lower the force needed to lift a load.
 - d) Wedges, which are two inclined planes joined back to back to form a sharp edge, are used to change the direction of a force and often result in the splitting of objects.
 - e) Screws, which are inclined planes wrapped around a cylinder, are used to raise and lower objects and hold objects together.
 - f) Pulleys, which are wheels with grooved edges for ropes, are used to change the direction of a pull and make it easier to lift a load.
 - g) Gears, which are wheels with teeth around the edge, are used to turn other gears and change the direction, speed, and force of circular motion.

More generally:

Recognize that simple machines help humans by: (a) decreasing the input force and increasing the input distance or (b) increasing the input force and decreasing the input distance needed to do work. Simple machines do not change the amount of work done

- 2) Identify examples of simple machines in everyday objects.
- 3) Identify simple machines within complex machines.
- 4) Choose appropriate simple machines to solve a mechanical problem.
- 5)
 - a) Define engineering design as the process of creating solutions to human problems through creativity and the application of math and science knowledge.
 - b) List and explain the following steps of the engineering design process:
 - i. Identifying a problem
 - ii. Researching possible solutions
 - iii. Picking the best solution
 - iv. Building a prototype
 - v. Testing the prototype
 - vi. Repeating any steps needed to improve the design

Simple Machines: Design a People Mover – Related National, State, and District Learning Standards

<p><u>Design a People Mover</u> <u>Learning Objectives</u></p> <p><i>By the end of this module, students will be able to:</i></p> <ol style="list-style-type: none"> 1) Explain what the following simple machines do to help humans: <ol style="list-style-type: none"> a) Levers, which are stiff bars that rotate around fixed points, make it easier to lift a load or apply a force. b) Wheel-and-axles, which are two differently-sized wheels attached to the same axis, are used to make circular motion easier. c) Inclined planes, which are surfaces slanted upwards, lower the effort needed to lift a load. d) Wedges, which are two inclined planes joined back to back to form a sharp edge, are used to change the direction of a force and often result in the splitting of objects. e) Screws, which are inclined planes wrapped around a cylinder, are used to raise and lower objects and hold objects together. f) Pulleys, which are wheels with grooved edges for ropes, are used to change the direction of a pull and make it easier to lift a load. g) Gears, which are wheels with teeth around the edge, are used to turn other gears and change the direction, speed, and force of circular motion. <p><i>More generally:</i></p> <p>Recognize that simple machines help humans by: (a) decreasing the input force and increasing the input distance or (b) increasing the input force and decreasing the input distance needed to do work. Simple machines do not change the amount of work done</p> <ol style="list-style-type: none"> 2) Identify examples of simple machines in everyday objects. 3) Identify simple machines within complex machines. 4) Choose appropriate simple machines to solve a mechanical problem. 5) a) Define engineering design as the process of creating solutions to human problems through creativity and the application of math and science knowledge. <ol style="list-style-type: none"> b) List and explain the following steps of the engineering design process: <ol style="list-style-type: none"> i. Identifying a problem ii. Researching possible solutions iii. Picking the best solution iv. Building a prototype v. Testing the prototype vi. Repeating any steps needed to improve the design 	<p><u>National AAAS Benchmarks</u></p> <p>4.F. 2nd Grade</p> <ul style="list-style-type: none"> - The way to change how something is moving is to give it a push or a pull. - Things move in many different ways, such as straight, zigzag, round and round, back and forth, and fast and slow. <p>4.F.5th Grade</p> <ul style="list-style-type: none"> - Changes in speed or direction of motion are caused by forces. The greater the force is, the greater the change in motion will be. The more massive an object is, the less effect a given force will have. <hr/> <p><u>National Science Education Standards</u></p> <p>Content Standard A: Science as Inquiry Pr(K-4)</p> <ul style="list-style-type: none"> - Identify a simple problem, propose a solution, implement proposed solutions, evaluate a product or design, communicate a problem, design, or solution <p>Content Standard B: Position and Motion of Objects Pr(K-4)</p> <ul style="list-style-type: none"> - The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull. <hr/> <p><u>Massachusetts Frameworks</u></p> <p>Grades 3-5, Technology/Engineering</p> <ul style="list-style-type: none"> - Identify and explain the difference between simple and complex machines, e.g. hand can opener that includes multiple gears, wheels, wedge gear, and lever. - Identify relevant design features (e.g., size, shape, weight) for building a prototype of a solution to a given problem. <hr/> <p><u>Somerville Science Benchmarks</u></p> <p>Materials & Tools Learning Standards, Grade 4</p> <ul style="list-style-type: none"> - Appropriate materials, tools, and machines extend our ability to solve problems and invent. - Identify and explain the difference between simple and complex machines, e.g. hand can opener that includes multiple gears, wheels, wedge gear, and lever. <p>Materials & Tools Benchmarks, Grade 4</p> <ul style="list-style-type: none"> - Discuss the difference between simple and complex machines (e.g. pulley vs. toy wagon).
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Lesson 1

What machines help people move?

Suggested Time

One 30-minute session

Lesson Overview

Students will be introduced to the overarching design challenge of building a people mover:

- Machines that move people up and over, and their pluses and minuses (trade-offs)
- Overall Design Challenge Introduction
- Trade-Offs Introduction
- Initial Design

Learning Objectives

By the end of this lesson, students will be able to:

- 5) a) Define engineering design as the process of creating solutions to human problems.

Vocabulary

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Trade-off – Plus and minus, positive and negative, the trading of one thing for another, usually perceived to be advantageous or complimentary.

Optimal – The best or most favorable.

Consultant – A person who gives professional advice.

Pitch – A brief presentation/summary of an idea used to convince others that one's solution or idea is best or optimal.

Materials

For each student

- Engineer's Journal Part 1

For the class

- Trade-off Chart

Preparation

- Distribute Engineer's Journals.
- Come up with some of your own examples for machines that move people up and across surfaces (up: elevator, escalator, stairs) (across: moving walkway, conveyor belt, slide)

Lesson 1**What machines help people move?*****Instructions for
Teachers******GETTING
STARTED******ACTIVITY
EXPLANATION*****PART I: Machines that Move People Up and Over (10 min)**

- 1) Explain to students that today they will begin working on their simple machines unit, which involves building a complex machine to move a LEGO person and its luggage.
- 2) Today is a warm-up for the students to begin thinking about machines. Ask students to brainstorm machines that lift humans UP, and machines that move humans OVER, as well as the pluses and minuses of each machine. They should discuss their ideas with their partner and then write their ideas in their Engineer's Journal. After two to three minutes of brainstorming, ask some students to share their examples.
- 3) Once students have given pluses and minuses about the machines, discuss how considering the good parts and bad parts about anything is called considering the trade-offs. With machines, we often talk about force and distance trade-offs. This may be a good time to point out the force and distance trade-offs chart both at the beginning of their journal and on a wall in the classroom. Explain that students will fill this chart out over the course of the unit.

PART II: Presentation of "Design a Complex Machine" Engineering Challenge (5 min)

- 4) Explain that by investigating simple machines, by the end of the unit, the students will not only be able to explain how some common machines work, they will also be able to design and build their own machines. To show what they have learned, students will tackle a grand engineering design challenge at the end of the unit.
- 5) Explain that, for this unit, students are consultants or professional advisers for an airport. The airport wants a new way to move people up and across surfaces simply and quickly. Once students have learned more about machines their job will be to make a model people mover.
- 6) The grand engineering design challenge for the unit will be to design a complex machine that moves a LEGO person up or down and across a surface, just like machines are used to help humans move. Students should keep this challenge in mind as they investigate each simple machine. They should keep asking, "How might this simple machine play a role in my people mover machine?"

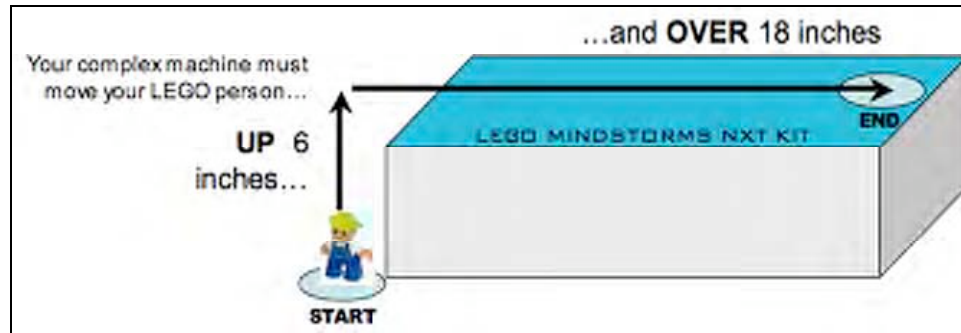
What Questions Might Students Ask During this Lesson?

- Which part of the trade-off is the RIGHT answer? *With trade-offs there is not one right answer. Depending on the situation one choice might be better than another.*
- What is a simple or complex machine? *We will learn more about both in the unit. For now just think of machines.*

Lesson 1

What machines help people move?

- 7) The formal design challenge is: Make a COMPLEX machine that can move a LEGO person UP 6 inches and OVER 18 inches (to the top of an NXT kit, and from one end of the kit to the other). Your complex machine must use at least three simple machines. *Once you turn your machine on, you may not touch your LEGO person until the end of the UP-and-OVER move.*



- 8) Explain that students will not only be challenged to move the LEGO person with their complex machine, but an optimal solution will move the LEGO person’s luggage, in the form of a weight.

PART III: Conceptual Design (15 min)

- 9) Allow students a few minutes to brainstorm what machines they might use to move the LEGO person up and over.
- 10) Remind them that once they have come up with their idea they also need to create a pitch or argument that will convince the airport staff that their people mover design is an effective and optimal solution.
- 11) If time allows have some students share their pitches with the class.

*STUDENTS’
INDEPENDENT
ACTIVITY*

Lesson 2

What are the seven simple machines?

Suggested Time

One 60-minute session

Lesson Overview

Students will be introduced to the term ‘machines’ and to the seven simple machines:

- Introduction to the concept that machines help humans,
- Introduction to the names and examples of the simple machines.

Learning Objectives

By the end of this lesson, students will be able to:

- 1) Explain that simple machines help humans.

More generally: Recognize that simple machines help humans by:
 (a) decreasing the input force and increasing the input distance or
 (b) increasing the input force and decreasing the input distance needed to do work. Simple machines do not change the amount of work done

- 5) Define engineering design as the process of creating solutions to human problems through creativity and the application of math and science knowledge.

Vocabulary

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Machine - A man-made device, usually driven by a motor or engine, with a system of interrelated parts that work together to perform a task.

Simple Machine - Anything that has few parts and makes it easier to do a task.

Complex Machine - A combination of two or more simple machines.

Lever - A stiff bar that rotates around a fixed point and makes it easier to lift a load or apply a force.

Pulley - A wheel with grooved edges for ropes that is used to change the direction of a pull and make it easier to lift a load.

Wheel - A disk or circular frame that revolves on an axle.

Axle - A pin, pole, or bar on or with which a wheel revolves.

Lesson 2**What are the seven simple machines?**

Wheel-and-Axle - Two differently sized wheels attached to the same axis that are used to make circular motion easier.

Screw - Inclined planes wrapped around a cylinder that are used to raise and lower objects and hold objects together.

Wedge - Two inclined planes joined back to back to form a sharp edge that are used to change the direction of a force and often result in the splitting of objects.

Inclined Plane - A surface slanted upwards that lowers the effort needed to lift a load.

Gear - A wheel with teeth around the edge that is used to turn other gears and change the direction, speed, and force of circular motion.

Materials

Note: The three items not in parenthesis are typically easier to acquire or we have given you them – the items in parenthesis are additional ideas.

For each student

- Engineer's Journal Part 2

For the class

- Transparencies or print-outs of photos of simple machines.
- Classroom set of simple machines for observation.
 - Levers: hammer, clothespin, light switch (stapler, pliers, bicycle brake, bottle opener, broom, baseball bat, paint key, cat's claw, crowbar, pencil, scissors, fishing pole).
 - Wheels and Axles: doorknob/faucet knob, LEGO wheel with axle, fan (cart/chair wheel, can-opener handle, overhead knob)
 - Inclined Plane: book positioned as a ramp, LEGO ramp, ramp picture (handicap ramp, slide, steps/stairs, highway ramp).
 - Screw: screw, spiral staircase picture, lightbulb (bottle top, drill bit, bolt, spinning stools).
 - Wedge: door jam, nail, staple (screwdriver, knife, scissor edge, axe, front of boat, airplane wing, saw, jackhammer).
 - Pulley: tape dispenser, LEGO pulley, clothes line (bicycle chain, window shade, elevator, garage door, stage curtain).
 - Gear: LEGO gear, metal gear, toy (disassembled motor from old kitchen appliance, bicycle gear, hand drill gear, inside of a clock).

Preparation

- Distribute Engineer's Journals.
- Find or build three examples of each simple machine. (NOTE: If you use a complex machine that includes a simple machine, be sure to highlight the part you want students to observe. You might use a sticky note to do so.)

Lesson 2**What are the seven simple machines?*****Instructions for
Teachers******GETTING
STARTED******ACTIVITY
EXPLANATION***

- Put each simple machine set into a bag so the sets can be passed around easily between groups or be set up at a station. Label each bag or set of items with numbers so that students' charts will be in the same order. Be sure station one is 'Screws' since the screw portion is already filled out on the student chart.

PART I: Thinking About Machines (20 min)

- 1) Tell students that they are about to begin a science unit that will help them learn how to design and build *machines*. To prepare for this unit, ask them to think about the machines that they use or see in their daily lives.
- 2) Ask students to use their Engineer's Journal to answer the three warm-up "exploration questions" about machines. Review the three questions with students: (1) What are two examples of machines that you use in your daily life? (2) Pick one of your example machines. What job do you think it does? (What problem does it solve?) (3) How do you think your machine works? (What do you think is inside the machine that makes it do its job?) Students should answer each of the three questions on page 2-1 by *drawing* their ideas, *labeling* their drawing, and *explaining* it in words. (This is the procedure for every exploration question.)
- 3) After four-to-five minutes of independent work on the exploration questions, ask students to share their examples of machines. Write down their ideas on a class chart.
- 4) After you have created a list of several machine examples, underline or circle the more complicated machines on the list. Ask students how many sentences they would need to explain how these machines work, or how many different parts are inside these machines. After a few students offer their thoughts explain that, because these machines are rather complicated to explain, they are called *complex machines*.
- 5) Explain that one of the goals of this science unit is to learn about the kinds of things that are inside complex machines. Another goal is to make it easier for students to talk about complex machines. To reach these goals, students will learn about another kind of machine, called a *simple machine*. Students will learn about seven special simple machines, and then they will put their knowledge together to design and build their own complex machines. By the end of the unit, they might even be able to explain the machine they just wrote about!

PART II: Simple Machine Observations (25 min)

- 6) Explain that to begin their investigation of simple machines, students will spend the rest of today's lesson exploring familiar examples of the seven types of simple machines. They will try to guess the names of the seven simple machines.

Lesson 2

What are the seven simple machines?

- 7) There are two ways to run this activity: (1) You can set up stations for each set of simple machines in different areas of the classroom and have students rotate between stations after a set amount of time. (2) You can sit the students in groups and have them pass the set of simple machines from group to group after a certain amount of time. In **both** cases, be sure to number the sets of items 1 – 7 so that students fill out the same part of the chart for the same set of simple machines. Since the first station (screws) will be done as a class, students should be placed into six groups.
- 8) Ask students to turn to page 2-2 in their Engineer's Journal. Review the activity's instructions with students. Students will rotate through each of the seven simple machine stations or pass each set of simple machines around.
- 9) With each set of items, students will select at least one example of a simple machine to write about. Students should write down at least one object that they see and what the object is used for. Finally, students should make a prediction for the name of the simple machine group from the list at the top of the table. If students have time, encourage them to write down more than one object and the job it performs for each set of items.
- 10) Point out to students that each box in their table has a station number and each set of objects also has a number. Tell them to be sure to write down the object and what the object is used for in the box number that corresponds to the number with the set of objects.

What Questions Might Students Ask During this Lesson?

- I don't know what job the machine I picked does or how it works. *Ask someone else in your group or pick another machine*
- What makes a machine simple? *A simple machine helps humans by changing the force they need to apply or a distance. You will learn how this works for every simple machine in future lessons..*
- Is a cup (or other object that looks uncomplicated) a simple machine? *If this is at the beginning wait until the end of the day to revisit and go through each simple machine with the class and see if the object fits.*
- Are these the only simple machines? *No, there are many more. These are just examples.*
- Don't scissors (or another object observed) also include another simple machine? *Yes, some machines have more than one simple machine and are called complex machines.*

Lesson 2

What are the seven simple machines?

STUDENTS' INDEPENDENT ACTIVITY

MAKING SENSE OF THE ACTIVITY

11) Before allowing students to start, tell them that they will do the first set of objects that are a simple machine as a class. Point out that the first row in the chart is already filled out for them as an example.

The object is:	The object is used to:	These objects are all examples of the simple machine called a:
(Station 1) Screw	Attach things together	My Predicted Name: Screw
Spiral Staircase Picture	Go up in a winding direction	Scientific Name:
light bulb End	Attach light bulb to socket	Screw

- 12) Hold up a screw and ask the students what the object is and what the object is used for. Repeat this process with a picture of a spiral staircase and a light bulb. Ask students for the name of the simple machine that the objects are all examples of. Remind them that all the names of the simple machines are included at the top of pages 2-2 and 2-3 in their Engineer’s Journal.
- 13) Remind students that they do not need to write down the object and its use for all items in a group. They should start with one object and then do a second object only if they have time.
- 14) Allow students to start their own object observations. Every 3 minutes, tell students to move to the next observation station or pass the objects to the next group. Depending on your class, you may be able to let students move between stations independently. If students do not know the name of the object tell them to ask their peers, take a guess, or a pick a different object in the set to write about.
- 15) Once students have seen all or most sets of simple machines, get students to return to their seats for a class discussion.

PART III: Simple Machine Discussion (15 min)

- 16) In order of the station numbers, hold up one example of each simple machine. Demonstrate how the simple machine moves and works. Discuss the jobs of more than one simple machine the students saw and what a possible common job or purpose would be for the entire set of objects. By the end of the discussion, students should know the simple machine group’s scientific name and write it down on their Simple Machines List.
- 17) Follow a similar procedure for all simple machines, making sure that students write down the scientific name for each simple machine group. Point out the location of the simple machine in each object if time permits. Remind the students that simple machines help people perform tasks.

Lesson 2**What are the seven simple machines?**

- 18) Inform them that they will learn about each simple machine in more detail as they work toward building their people mover. In particular they will learn:
- How machines make it easier to lift, cut (or split), raise, lower, and move objects.
 - How machines can be used to change the direction, speed, and amount of effort needed for these tasks.
- 19) Ask students which simple machines might be involved in some of these jobs. For example: what simple machine(s) might help lift an object? What simple machine(s) might change the direction or speed of lifting? If students mention two simple machines for the same job, explain that often there is more than one way for engineers to do the same task. Engineers then have to make design choices based on the desired outcome. They might have to make design choices between simple machines when they build their own complex machines!

Lesson 3

What happens when we change a lever's rotation point?

Suggested Time

One 60-minute session

Lesson Overview

Students will be introduced to the mechanics of levers and the ways levers can help humans.

- Class discussion about how a hammer can be used to remove a nail from a board.
- Introduction of key lever vocabulary (load, force, distance, rotation point) through demonstrations of a prying lever.
- Building weight-lifting levers.
- Investigating weight-lifting levers.

Learning Objectives

By the end of this lesson, students will be able to:

- 1) Explain what the following simple machines do to help humans:
 - a) Levers, which are straight bars that rotate around fixed points, make it easier to lift a load or apply a force.

Vocabulary

Lever - A straight bar that rotates around a fixed point and makes it easier to lift a load or apply a force.

Rigid - Not flexible, stiff.

Pry - To move, lift, or open with something that acts as a lever.

Rotate - To turn or cause to turn around an axis or a center.

Rotation Point - The axis or center that a wheel or disk spins.

Work - The use of force to move an object a certain distance.

Force - A push or a pull.

Distance - The space between two points, lines, surfaces, or objects.

Load - The object being lifted or moved by a machine.

Lever Arm - Part of lever that goes around the rotation point and has a force applied to it.

Horizontal - On the same level as the horizon or line of the floor.

Lesson 3**What happens when we change a lever's rotation point?**

Trade-off - Plus and minus, positive and negative, the trading of one thing for another, usually perceived to be advantageous or complimentary.

Materials**For each student**

- Engineer's Journal Part 3

For each student pair

- LEGO NXT kit
- Weighted LEGO brick or other weight
- Tape
- Small paper ruler marked in centimeters

For the class

- Piece of wood measuring at least 1"x2"x6"
- Nail
- Hammer with claw
- Transparencies or print-outs of various levers

Preparation

- Distribute Engineer's Journals.
- Build example(s) of weight-lifting levers
- Use the hammer to pound the nail into the piece of wood

**Instructions for
Teachers****GETTING
STARTED****PART I: Introductory Discussion (5 min)**

- 1) Explain that in this lesson students will start to learn about their first simple machine, levers. Remind them of the examples of levers they saw in the first lesson: clothespin, hammer, and light switch – or whatever lever examples you selected.
- 2) Explain that the curved end of the hammer, commonly called the claw, is considered an example of a lever.
- 3) Instruct students to turn to page 3-1 in their Engineer's Journal and think about if the teacher (you) would be strong enough to pull a nail out of a board if you just pulled up on the hammer. Instruct students to write why they think the teacher would or would not be strong enough and a way that would be worse or better to use the hammer to pull the nail out of the board with the hammer.

Lesson 3

What happens when we change a lever's rotation point?

PART II: Rotation Point Demonstration (10 min)

- 4) Explain to students that now they are going to see what happens when a nail is pulled out of a board with a hammer, and find out some scientific ways to think about removing a nail from a board.
- 5) You will use a wooden board, nail, and hammer to introduce one feature of every lever: rotation points. Hold up the wooden board with the protruding nail, and then set it down. Hold up the hammer and point out the claw portion that is used to remove nails. Place the hammer claw around the nail and hold the hammer vertically.
- 6) Ask the students by a show of hands how many predicted you were strong enough or not strong enough to remove the nail by pulling only UP with the hammer. Then, try to pull the nail out by pulling only up (do not rest the hammer head on the board at all). If the nail has been properly hammered into the board, you should NOT be able to pull it out with only an upward tug on the hammer claw.
- 7) You've revealed that you cannot remove the nail just by pulling up with the hammer. Ask the students to think of how else the hammer claw might be used to remove the nail. Try out some of their suggestions if possible.
- 8) Demonstrate how the hammer claw is typically used to remove a nail. Ask students what is different about your new technique. Point out that you must rest the top of the hammer head on the board, and then you must push DOWN on the hammer arm, as the hammer claw pulls UP on the nail.
- 9) Emphasize that the hammer claw only worked after you rested it on the board – in other words, when you found a spot it could “rotate” around. Explain that when you tried to get the nail out just by pulling the hammer claw up, the technique didn't work because it was missing one essential feature of a lever – a rotation or pivot point. When you rotated the hammer claw around the point on the board, it worked because it had a rotation point. ***Every lever needs this rotation point.***
- 10) Ask students to think about what kind of “work” the hammer claw lever performed. Review how work in a science context is different than going to work or doing homework.
- 11) Explain that any time work is done, a *force* (a push or pull) is applied to an object and the object moves some distance. Explain that you might call the hammer's work *prying* work.
 - Explain that in the hammer example the *force* was how hard the teacher pushed or pulled on the hammer.
 - The *distance* was how far the hammer moved around the rotation point when the teacher applied the force.

Note: You may want to have a second nail hammered into the board to demonstrate how the force is put on the handle of the hammer and the distance is how far the hammer handle moves.

Lesson 3**What happens when we change a lever's rotation point?**

Note: Depending on the class you may be able to elicit the features of a lever from the students through the use of questions such as: what did we say all levers needed to have or is there a way you can describe all the arms of levers?

Note: To solidify students' understanding of lever features you might mention examples of levers in the human skeletal system. The elbow is a good example of a lever that multiplies input distance rather than input force.

- 12) Explain that when the hammer is pulled straight up, no work is done because no distance is moved. The hammer is not used as a lever because the hammer handle and the nail do not move around a rotation point. When the nail is actually removed, the force on the handle makes it curved downward (the distance it moves) and work is done, causing the nail to be removed.
- 13) Once students have a clear sense of the force, distance, and load elements of the hammer, have them label where they are located when a hammer is pulling a nail out of a board on the picture on page 3-2 of their Engineer's Journal.

PART III: Lever Features (5 min)

- 14) Summarize **the four features** that make the hammer claw is a lever: (a) it is stiff, (b) it moves a load (the nail), (c) it rotates around a point, and (d) it makes your work easier by multiplying your force so that it is enough to pull a nail out of the wood.
- 15) Write these features on the board and instruct students to write them on page 3-2 in their Engineer's Journal.
- 16) Remind students of the levers they know of currently: hammer, light switch, and clothespins.
- 17) If students are having trouble seeing or understanding the lever features or locations of force, distance, rotation point, and load; draw the light switch and clothespin on the board and label the lever features.

PART IV: Lifting Lever Building (20 min)

- 18) Explain that the students will now have a chance to make their own levers.
- 19) Ask students to turn to page 3-3. Review the building instructions by asking students to follow along as you build a complete lever in front of the class.
- 20) Point out to students that they will build three lifting levers with different rotation points: one in the middle, one 6 studs from the end of the beam where the load will be, and one 5 studs from the other end (the end of the beam where the force is applied).

Part V. Lifting Lever Investigation (20 min)

- 21) Explain that students will make two observations for each of three designs of their lever. The two observations are the **force** needed to move the load and the **distance** they have to apply the force. The three lever designs are identified as: rotation point near the load, rotation point in the middle, and rotation point far from the load.

Lesson 3

What happens when we change a lever's rotation point?

*ACTIVITY
EXPLANATION*

Note: Make sure students use their pinky to push on the lever. It is easier to feel the change in force when they use their pinky.

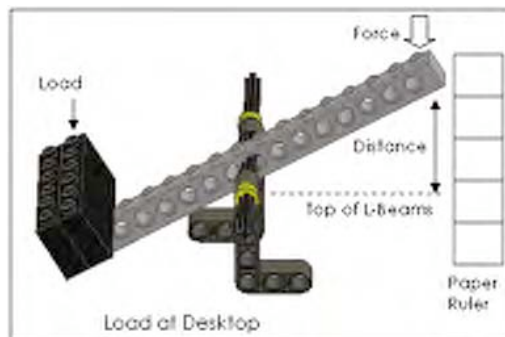
Note: One way to measure the distance is to fold the paper ruler so that zero is where the end of the lever opposite the load is. Then push the lever down until it is level/at the top of the L-beams. The distance is the number where the end of the lever is.

Note: You may want to give students three paper rulers so they can mark the distance for each lifting lever separately. You could also give them a piece of paper and just have them make marks on it for the distance and then measure the distances in cm with the paper rulers or actual ruler. Whatever method you use, be sure to demonstrate for students.

*STUDENTS'
INDEPENDENT
ACTIVITY*

22) Ask students to follow along as you use your lever to demonstrate the force and distance investigation steps (page 3-4). If possible, re-create the chart from page 3-5 on the board (or overhead projector) and demonstrate how to fill in the boxes.

- i. Attach a weighted brick to one end of the lever arm. This heavy brick is a model of a *load* that needs to be moved to a higher location.
- ii. Use the lever to lift the brick into the air (by pushing down on the other end **with your pinky**). Notice how much force you have to apply. Move the load to the other two levers and notice how much force you have to apply to all three levers. Record the measurements on journal page 3-5. One lever will take a lot of force, one lever will need a medium amount of force, and one lever will take a little force.



- iii. Now measure the distance you need to move the lever to make the load come to the top of the L-beams. Make measurements by rounding to the nearest centimeter, using the paper ruler supplied. Record the measurements for each lever.

- 23) Allow 5 minutes for initial lever investigating. After this initial period, address any common difficulties that students are experiencing.
- 24) After 10 minutes of investigating, tell students that they have 5 more minutes left to finish their investigations.
- 25) If students finish early instruct them to complete the questions on page 4-1 on lever trade-offs.

What Questions Might Students Ask During this Lesson?

- How do we know when work is not being done? *If an object does not move a distance OR there is no force applied or push/pull, no work is done.*
- Why do levers need rotation points? *If there was not a rotation point a lever would only stay in one place and not move through a distance. If the lever does not move a distance, it is not doing any work and would not be helping humans!*
- Which side do I push on? *The side of the lever opposite the LEGO weight.*
- Which side do I measure the distance on? *The side of the lever you push on or opposite the LEGO weight.*
- How do I measure the distance again? *Fold the ruler so that side of the lever opposite the weight starts at zero. Push down until the weight is as high as the top of the L-beams or horizontal. Read where the lever arm is now on the ruler. This is the distance.*
- I already wrote down the first lever only took a little, but this one took less! *It is okay to cross out and write a different observation. You could also wait until you did all three observations and then write your force observations down.*

1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7
1	1	1	1	1	1
2	2	2	2	2	2
3	3	3	3	3	3
4	4	4	4	4	4
5	5	5	5	5	5
6	6	6	6	6	6
7	7	7	7	7	7

Lesson 4

What are other types of levers?

Suggested Time

One 60-minute session

Lesson Overview

Students will discuss how a lever's rotation point affects the applied force and distance, as well as be introduced to the mechanics of two-armed levers and the ways they can help humans.

- Finish investigating weight-lifting levers if necessary.
- Class discussion about how changing a lever's rotation point affects the applied force and distance.
- Compare and contrast common levers: staplers, kitchen tongs, brooms.
- Everyday examples of levers.

Learning Objectives

By the end of this lesson, students will be able to:

- 1) Explain what the following simple machines do to help humans:
 - a) Levers, which are straight bars that rotate around fixed points, make it easier to lift a load or apply a force.
- 2) Identify examples of simple machines (levers) in everyday objects.
- 3) Identify simple machines (levers) within complex machines.

Vocabulary

Lever - A straight bar that rotates around a fixed point and makes it easier to lift a load or apply a force.

Rotate - To turn or cause to turn around an axis or a center.

Rotation Point - The axis or center that a wheel or disk spins around.

Work - The use of force to move an object a certain distance.

Squeeze - To press something firmly together from both sides.

Force - A push or a pull.

Distance - The space between two points, lines, surfaces, or objects.

Load - The object being lifted or moved by a machine.

Lever Arm - Part of lever that goes around the rotation point and has a force applied to it.

Trade-off - Plus and minus, positive and negative, the trading of one thing for another, usually perceived to be advantageous or complimentary.

Lesson 4**What are other types of levers?****Materials**

Note: Materials for each student pair are only needed if students have not completed the lifting lever observations and need to complete them today.

Preparation**Instructions for Teachers****MAKING SENSE OF THE ACTIVITY****For each student**

- Engineer's Journal Part 4

For each student pair

- LEGO NXT kit
- Weighted LEGO brick or other weight
- Paper ruler

For the class

- Kitchen tongs
- Nutcracker
- Transparencies or print-outs of various levers

- Distribute Engineer's Journals.
- Build example(s) of weight-lifting levers
- Bring in nutcracker and kitchen tongs from home if available

PART I: Lifting Lever Trade-off (10-20 min)

- 1) If needed allow students more time to complete their lever observations.
- 2) Remind students of the force and distance observations they made in the last lesson. Have students turn to page 4-1 in their Engineering Journal and give them 2-to-3 minutes to answer the questions based on their observations.
- 3) As a class, discuss which case requires the least force (when the rotation point is far away from the load) and which case requires the least distance (when the rotation point is near the load).
- 4) Talk about how this kind of situation is called a trade-off. There is a plus and a minus about putting the rotation point in different places. A rotation point near the load requires more force and less distance, while a rotation point far away from the load requires less force and more distance.
- 5) Based on this discussion fill in the first box in the provided classroom trade-off chart. Have students also fill out this portion of the chart in their Engineer's Journal.
- 6) Explain to students that there are trade-offs like this for all of the simple machines and that they will be revisiting the chart and filling it out throughout the unit.

Lesson 4

What are other types of levers?

GETTING
STARTED

PART II: Grouping Levers: One-Armed and Two-Armed (10 min)

- 7) Explain that today students will have the opportunity to learn much more about another kind of lever: two-armed levers.
- 8) Direct students to complete the two exploration questions on page 4-2 in their Engineer's Journal: (1) If they have kitchen tongs, a broom, and a stapler, which two objects would they put in the *same* group and why? (2) If they had to put **ALL** three objects in the same group what are some reasons they could be put together?
- 9) After 3-to-5 minutes of work, ask a few students to volunteer their ideas. Record the ideas on the board. If no student mentions that they would group staplers and kitchen tongs together because they have two-arms be sure to bring it up.
- 10) For grouping all three items, if no student mentions that the items (1) have straight, non-bendable parts, and (2) all rotate or swivel, add those two ideas to the board.
- 11) Then reveal that tongs, brooms, and staplers are actually all examples of levers. Point out the similarities between the objects that make them levers. Levers: (a) are stiff, (b) move a load, (c) rotate around a point, and (d) makes your work easier by multiplying your force. There are many different kinds of levers, and today you will learn about them by looking at two-armed everyday examples of levers.

What Questions Might Students Ask During this Lesson?

- Which trade-off is 'right' or where should we always put our lever's rotation point? *There is not only one place to put the rotation point or one 'right' trade-off. Depending on what you want to use the lever for, you will need to make decisions about whether it is more important to apply less force or push on a lever for a small distance.*
- Why would you ever want to move a short distance and apply a lot of force? *If you only had a small space to work in or if neither force were very large.*
- Why isn't the force applied in the same place for different levers? *The location of applied force depends on what the lever is being used for and the type of lever.*

ACTIVITY
EXPLANATION

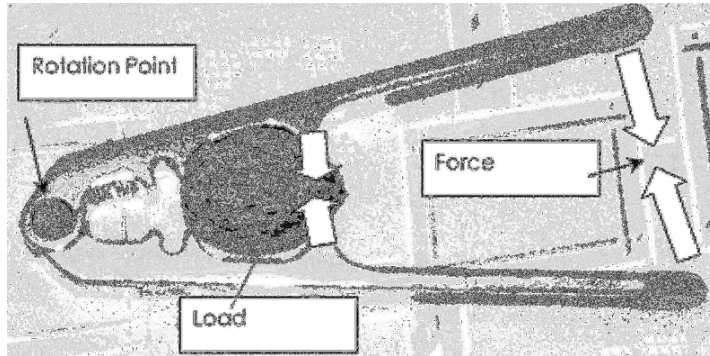
PART III: Force, Distance, and Load in Two-Armed Levers

- 12) Hold up a nutcracker. Demonstrate how the nutcracker helps you break or open up nut shells.
- 13) Explain that even with two arms, levers still have a rotation point, move a distance, and need a force applied to them to do work. The nutcracker is a two-arm lever and the hammer claw was a one-arm lever.
- 14) Ask students for their definitions of force, distance, and rotation point in order to review the terms.
- 15) Ask students to turn to page 4-3 in their journals and predict the locations of the nutcracker's *rotation point, force, and load.*

STUDENTS'
INDEPENDENT
ACTIVITY

Lesson 4**What are other types of levers?**

- 16) Make a quick sketch of the tongs on the board. Write the words *rotation point*, *force*, and *load* nearby. Draw arrows to the appropriate locations and ask students to correct their papers.



- 17) Have students think about the different distances the nutcracker can move to break a nut or load. Explain that nutcrackers apply force over different distances depending on the size of the nut. Have students answer whether the distance would be shorter or longer for a bigger nut and explain their answer on page 4-3 of their Engineer's Journal.
- 18) Explain to students that there are two forces involved when a nutcracker works. Have students think about how there is an effort or input force that the human applies, as well as an output force that the nutcracker applies on the nut. Have students answer where the output force is in the nutcracker and what job the output force does in the nutcracker on page 4-3 of their Engineer's Journal.

PART IV: Concluding Class Discussion (20 min)

- 19) Begin the wrap-up discussion by reiterating the two ways that levers make work easier for humans: all levers either reduce the force you must exert to get a job done (but require more distance), or reduce the distance you have to put in to get a job done (but require more force).
- 20) Ask students where they think the best location for the rotation point of a lever is, based on their investigations. As you listen to ideas, ask students to justify their answers. Remind students that there is a disadvantage and an advantage (i.e., a minus and a plus) to any change in rotation point location.
- 21) Ask students to answer the questions on page 4-4 in the Engineer's Journal: (1) what are some one-armed levers that you can think of? And, (2) what are some two-armed levers that you can think of? Some lever examples are a hammer, clothespin, light switch, stapler, pliers, bicycle brake, bottle opener, broom, baseball bat, paint key, cat's claw, crowbar, pencil, scissors, chopsticks, and fishing pole.
- 22) On page 4-5 instruct students to make changes to their people mover design based on what they have learned about simple machines.

MAKING SENSE OF THE ACTIVITY

Note: *The human skeletal system provides good examples of levers. The elbow is a good example of a lever that multiplies input distance rather than input force. Brooms and bats are interesting examples because they use the point of contact between the human and the object as the rotation point.*

Lesson 5

How do wheel-and-axle systems work?

Suggested Time

One 60-minute session

Lesson Overview

Students will be introduced to the uses of wheels and axles and the ways wheels and axles can help humans.

- Thinking about common uses of wheels and axles and how wheels and axles can be used to move objects.
- Building a model of a wheel-and-axle.
- Distinguishing the wheel and the axle part of wheels and axles.

Learning Objectives

By the end of this lesson, students will be able to:

- 1) Explain what the following simple machines do to help humans:
 - b) Wheel-and-axles, which are two differently-sized wheels attached to the same axis, are used to make circular motion easier.
(Wheels are circular rotating objects that make moving other objects easier. Axles are linear bars that connect together with wheels to move other objects more easily.)
- 2) Identify examples of simple machines (wheel-and-axles) in everyday objects.
- 3) Identify simple machines (wheel-and-axles) within complex machines.

Vocabulary

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Wheel - A disk or circular frame that revolves on an axle.

Axle - A pin, pole, or bar on or with which a wheel revolves.

Wheel-and-Axle - Two differently sized wheels attached to the same axis that are used to make circular motion easier.

Force - A push or a pull.

Background Information

- Rolling Wheels – By reducing friction, *wheels* help us move objects along. Objects that use wheels for easier movement include skateboards, wheelbarrows, wagons, scooters, toy cars, equipment carts, and desk chairs. On most of these objects, the wheels turn freely on fixed *axles* (thin rods). The purpose of these axles is simply to hold the wheels in line. The axles are not used to make the wheels turn. Instead, the wheels turn because you push or pull somewhere else on the object. You do not put effort (a push or a pull) directly into the wheels.
- Wheel-AND-Axle SYSTEM – A *wheel-and-axle system* is different from *rolling wheels*. In a wheel-and-axle system, the purpose of the wheel-and-axle

Lesson 5**How do wheel-and-axle systems work?**

is to make each other turn. When you use an object with a wheel-and-axle system, you apply effort (a push or a pull) directly to the wheel or axle, rather than to somewhere else on the object. If you apply effort to the wheel, the axle turns. If you apply

- The back wheel of a bicycle is also an example of a wheel-and-axle system. The back wheel of the bike only turns when you put effort into the back axle by pedaling. (The bicycle's gears and chain move your pedaling effort from the pedals to the back axle.)
- The front wheel of a bicycle is *not* a wheel-and-axle system. It is just a rolling wheel that turns freely on the fixed front axle. You do not put effort into the front axle to make the front wheel turn. Instead, the front wheel turns by itself whenever the bike is moving.

Materials**For each student**

- Engineer's Journal Part 5

For each pair of students

- Plastic or paper bowl filled with small-size pasta, 1x2 LEGO bricks, dry beans, dry peas, beads, or other dry granular substance.

For the class

- Food mixer and whisk or pictures of them.

Preparation

- Distribute Engineer's Journals.
- Bring in a food mixer, whisk, and hand food mixer if you have them at home.
- Build example food mixer model.
- Review background information on rolling wheels and wheel-and-axle

**Instructions for
Teachers****GETTING
STARTED****PART I. Wheel-and-axle/Rolling wheels Introduction (10 min)**

- 1) Explain that today students are going to investigate a simple machine called the wheel-and-axle. Explain that different people define the wheel-and-axle simple machine in different ways: some include *rolling wheels* in their definition, while others include only specific *wheel-and-axle systems* in their definition. Write these two phrases on the board. Then explain that since you want your students to understand both definitions, today they will talk about examples of both and explore one in more detail.
- 2) To warm up for the investigations, direct students to answer the exploration question on page 5-1 of their journals. This page shows two groups of objects: Group 1 with a steering wheel and a hand egg beater, and Group 2 with a stroller and a skateboard. The exploration question asks: One group of objects shows examples of *rolling wheels*. The other shows examples of *wheel-and-axle systems*. Which is which? Why do you think so?

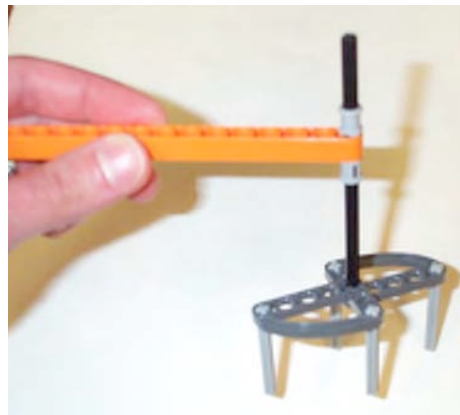
Lesson 5

How do wheel-and-axle systems work?

- 3) Allow 2-to-3 minutes for work on the exploration questions. Then ask students to share and justify their ideas. After hearing a few ideas, clarify that skateboards and strollers have rolling wheels, while egg beaters and steering wheels are examples of wheel-and-axle systems. Use the background information to offer a brief (2-to-3 minute) mini-lecture on the difference between rolling wheels and wheel-and-axle systems.
- 4) Explain that it is okay if students do not fully understand the difference between “rolling” wheels and wheel-and-axle systems right now. To learn more, they will build a machine that uses a wheel-and-axle system. To help students solidify their understanding of rolling wheels you might also ask students the following questions about an object that has “rolling” wheels. One of the examples included in the following questions should suffice:
 - Why are skateboards, strollers, or wagons examples of “rolling” wheels rather than wheel-and-axle systems?
 - How do the wheels help us do work with a skateboard, stroller, or wagon? (Would the skateboard, stroller, or wagon help us if it didn’t have wheels?)
- 5) State that the big science question for the next activity is “How can we design wheels and wheel-and-axles systems to help us do work?” Write this question on the board.

PART II. Wheel-and-Axle System – Food Mixer (35 min)

- 6) Explain that students will now work independently to build an example of a wheel-and-axle system – a food mixer.



- 7) If possible show students a whisk and an electric food mixer. A picture will also suffice. These are the real world machines that they will be modeling with LEGO materials.

What Questions Might Students Ask During this Lesson?

- How do I connect the handle to my mixer? *Put a LEGO handle on the axle and slide it down so that the axle sticks out. Put the 5- or 15-hole rounded beam onto the axle and peg on the handle. Attach another peg to the end of the beam.*
- How do I get my mixer to turn? *Hold the long beam and turn the handle or axle.*
- How do I stop the bowl from spinning? *Work with your partner. One person tests the mixer while the other holds the bowl in place.*
- What distance are we saying is shortest, medium, or longest? *How big a circle you have to turn the top of the mixer. The axle and handles make differently sized circles.*
- I don’t think any of the handles need a lot of force to turn! *Pick the handle that needs the most force and fill in its distance box with a lot.*

*ACTIVITY
EXPLANATION*

Lesson 5**How do wheel-and-axle systems work?***STUDENTS'
INDEPENDENT
ACTIVITY*

- 8) Review the food mixer building instructions on journal page 5-2. Show students your pre-built model. Demonstrate how to hold the 15-hole beam with one hand while turning the mixer axle with the other hand.
- 9) Explain that when working with their partner one student should hold the bowl in place while the other uses the handle. Also, they should turn their LEGO food mixer **gently** in order to avoid making the mixed substance leave the bowl.
- 10) Ask students what is missing from your model that is not missing from the real food mixers. A handle! Ask them to predict what kind of handle design will make the food mixing work the easiest. For each prediction, ask what may be the trade-offs (i.e., pluses and minuses) of that design.
- 11) Have students turn to the food mixer observation chart on page 5-3 in their Engineer's Journal. Point out that they will be making two handles to add to the food mixer with the pieces shown and then they will be able to create their own handle.
- 12) Explain that students will make two observations on each of the handle designs: (1) How much force does it take to mix the food? and, (2) How far a distance (or how big of a circle) does the mixer need to be turned? The pre-set handle designs will receive a little, a medium amount, or a lot for a force rating and a shortest, medium, or longest for a distance rating. Remind students that they might change their answers once they turn all three handle designs. They can just cross out their old answers or wait until they have tested all the handles to write their answers down. You may need to explicitly tell students that each rating should be used only once.
- 13) Explain that if students finish early, they can build a second food mixer of their own design. Then they will have two different models to test, and they will learn more about how to design wheel-and-axle systems to help us do work.

PART III: Wheel-and-Axle Trade-offs (10 min)

- 14) As students finish their observations, point them to the questions about force and distance on page 5-4 in their Engineer's Journal. Allow students 2-to-3 minutes to complete the questions and then briefly discuss their answers.
- 15) Talk about how wheel-and-axles also have a trade-off. A long wheel-and-axle requires less force to turn, but more distance. A short wheel-and-axle requires more force, but less distance.
- 16) Based on this discussion fill in the wheel-and-axle box in the provided classroom trade-off chart. Have students also fill out this portion of the chart in their Engineer Journals.

*MAKING SENSE
OF THE ACTIVITY*

Lesson 5**How do wheel-and-axle systems work?**PART IV: Wheel-and-Axle Examples (5 min)

- 17) If there is time, ask students to answer the question on page 5-4 in the Engineer's Journal: What are some examples of wheel-and-axle systems that you can think of? Some wheel-and-axle examples are door/faucet knobs, LEGO wheel with axle, fan, cart/chair wheel, can-opener handle, and overhead knob.
- 18) On page 5-5 instruct students to make changes to their people mover design based on what they have learned about simple machines.

Lesson 6

How do inclined planes, screws, and wedges work?

Suggested Time

One 60-minute session

Lesson Overview

Students will be introduced to the uses of inclined planes, screws, and wedges and the ways inclined planes, screws, and wedges can help humans.

- Consider steep and gentle inclined planes.
- Test inclined planes to determine which require the least force.
- Introduction to screws and wedges.
- Finding the inclined planes in screws and wedges.
- Finding screws and wedges in everyday objects.

Learning Objectives

By the end of this lesson, students will be able to:

- 1) Explain what the following simple machines do to help humans:
 - c) Inclined planes, which are surfaces slanted upward, lower the effort needed to lift a load.
 - d) Wedges, which are two inclined planes joined back to back to form a sharp edge, are used to change the direction of a force and often result in the splitting of objects.
 - e) Screws, which are inclined planes wrapped around a cylinder, are used to raise and lower objects and hold objects together.
- 2) Identify examples of simple machines (inclined planes, screws, and wedges) in everyday objects.
- 3) Identify simple machines (inclined planes, screws, and wedges) within complex machines.

Vocabulary

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Inclined Plane - A surfaces slanted upward that lowers the effort needed to lift a load.

Screw - Inclined planes wrapped around a cylinder that are used to raise and lower objects and hold objects together.

Wedge - Two inclined planes joined back to back to form a sharp edge that are used to change the direction of a force and often result in the splitting of objects.

Spring Scale - A device for weighing that uses a hanging spring to measure the weight of an object.

Lesson 6**How do inclined planes, screws, and wedges work?****Materials**

Note: You may use other weights and spring scales, but the weight value should be taken into consideration when choosing the spring scale. For example, you can use a 1-Newton spring scale with a 75-g weight. But you cannot use a 1-Newton spring scale with a 200-g weight; this spring scale would not measure the 2 Newtons of force exerted by a 200-g weight.

Preparation**Instructions for Teachers****GETTING STARTED**

Steep - Having a very sharp slope or incline.

Gentle - Having a gradual or mild slope or incline.

Force - A push or a pull.

For each student

- Engineer's Journal Part 6

For each pair

- 1-Newton Spring Scale (Force Meter)
- LEGO Weight
- Tape
- LEGO NXT kit

For the class

- Transparencies or print-outs of photos of screws and wedges
- Tape measure (optional)
- Screw (optional)
- Knife (optional)

- Distribute Engineer's Journals.
- Build example LEGO cart
- Put masking tape on the edges of each student pair's desk
- Bring in some examples of screws and wedges from home (examples from Lesson 1 could be repeated)

PART I: Introduction to the Trade-Offs of Inclined Plane Design (5 min)

- 1) Direct students to the exploration question for the lesson: Which would be easier to walk up: a steep ramp or a gentle ramp, and why? (Another way to think about this question is: if you needed to build a ramp to get strollers or wheelchairs up to a certain level, would it be better to build a gentle ramp or a steep ramp?) You might need to review the terms *gentle* (i.e., not steep) and *steep*. Students should draw and write their ideas in their Engineer's Journal.
- 2) After 2-to-3 minutes of work on the exploration question, ask some students to share their ideas.
- 3) If the issue of ramp *length* has not been raised (i.e., if all students think the gentle ramp would be better because it does not take as much force to walk up), ask students to imagine two ramps leading up to their desks: one steep and one gentle. Then ask if one ramp

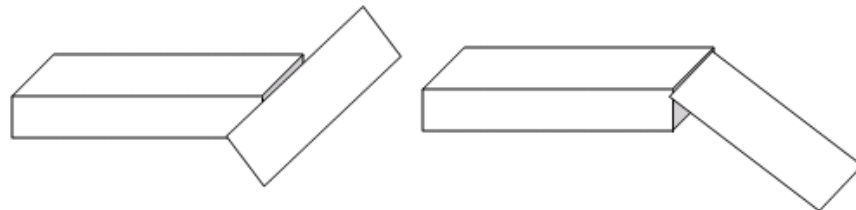
Lesson 6**How do inclined planes, screws, and wedges work?***ACTIVITY
EXPLANATION #1*

would need to be longer than the other. Help students visualize that to reach the same height, a gentle ramp must be much longer than a steep ramp. You could demonstrate this with a tape measure.

- 4) This is the trade-off in designing ramps or any other inclined planes. To reach a certain height a steep ramp requires a short distance, but it takes a lot of force to take each step up the steep ramp. To reach that same height, a gentler ramp requires a longer distance, but it takes less force to take each step up the gentle ramp.
- 5) Point out that, on page 6-1 in their Engineer's Journal, the steep ramp and the gentle ramp end up at the same height, but the steep ramp slope is much shorter than the gentle ramp slope (diagonal part). You might even ask students to measure the two ramps with rulers.

PART II: Ramp Set-Up and Spring Scale Demonstration (15 min)

- 6) Explain that in today's investigation, students will explore how ramps make lifting work easier, and they will compare steep ramps, gentle ramps, and no ramp at all. Students will use a LEGO cart to pull a weight up a steep ramp, up a gentle ramp, and straight up in the air. Their goal is to find out which method of lifting (steep ramp, gentle ramp, or no ramp) requires the most force, and which method of lifting requires the most distance?



Steep Ramp with Wide Edge on Box

Gentle Ramp with Narrow Edge on Box

- 7) Instruct students to turn their Engineer's Journal to page 6-2 to review the cart building instructions. Display a pre-built sample cart.
- 8) Also have students turn to page 6-3 to review the ramp set-up instructions. For the steep ramp, students should place the lid so that its widest edge rests on the box top. For the gentle ramp, students should place the lid so that its narrow edge rests on the box top. Before each ramp test, students should tape the lid to the box top.
- 9) Show students a spring scale, which is also called a *force meter* because it measures force. Demonstrate how to use the spring scale to measure the force needed to move a cart and weight. First, make sure your sample cart has a LEGO weight, and then hook the scale to one of the cart's axles. Second, show how to read the scale when the cart and weight are hanging freely. Third, show how to read the scale when the cart and weight are resting on the middle of an inclined plane. (These steps are on page 6-3 in the Engineer's Journal.)

Lesson 6

How do inclined planes, screws, and wedges work?

STUDENTS'
INDEPENDENT
ACTIVITY #1MAKING SENSE
OF THE ACTIVITYACTIVITY
EXPLANATION #2

- 10) Distribute spring scales. Have the students practice using the scales to measure the force needed to lift something up. Explain that students should read the scale in Newtons rather than in grams.

PART III: Testing Inclined Planes (20 min)

- 11) Pass out the LEGO kits and LEGO weights to construct their carts.
- 12) Visit student groups and assist them as they begin taking spring scale readings.
- 13) Remind students that their goal for today is to find out which ramp requires the least force to lift a load up to a certain height. Remind students that their ramps are examples of the *inclined plane* simple machine.
- 14) When students have recorded all the measurements, they should fill out the summary questions on the bottom of page 6-3 in their Engineer's Journal. These questions summarize how an inclined plane's length and steepness affect the force needed to lift an object.
- 15) Allow 15 minutes for building and completing the questions. Instruct students to take their carts apart and clean up their kits once they have completed all observations.
- 16) Clarify three main ideas about inclined planes:
- Inclined planes make it easier to move things to a certain height by reducing the *force* required to lift.
 - However**, inclined planes require objects to be moved over longer distances than the vertical distance. The gentler the inclined plane, the longer the distance (but the lower the force or lifting effort needed).
 - The steeper the inclined plane, the shorter the distance (but the greater the force or lifting effort needed).
- 19) Have students fill out the inclined planes trade-off in their chart.

PART V: Screws and Wedges as Inclined Planes (20 min)

- 17) Explain that for the final portion of today's lesson, the students are going to apply their new knowledge about inclined planes to find the

What Questions Might Students Ask During this Lesson?

- I'd rather use the steep ramp and take less time. Is that wrong? *Taking less time since it is shorter is a great reason to pick the steep ramp. With trade-offs there is no right or wrong answer.*
- The reading on my spring scale keeps changing. *Pull the cart and weight up the ramp gently and try to always pull on it with the same force. If it still keeps changing, pick a reading in the middle.*
- Why are screws and wedges simple machines if they have inclined planes in them? *Screws and wedges have force-distance trade-offs and help humans, characteristics of simple machines.*

Lesson 6**How do inclined planes, screws, and wedges work?**

Note: A screw can be modeled by wrapping a triangular piece of paper around a pencil. Draw along the slanted edge of the triangle in dark marker to make the wraps of the screw clearer.

**STUDENTS'
INDEPENDENT
ACTIVITY #2**

inclined planes “hidden” in two other simple machines.

- 18) Explain that inclined planes are so useful that they can be built into other objects. Two ways of using inclined planes as part of other objects are so common that they have their own simple machine names.
- 19) Hold up a screw (or instruct students to look at the photo of a screw and spiral staircase on page 6-4) and ask students to try to find the inclined plane “hidden” in these “machines.” After hearing a few student ideas, clarify that the inclined plane is the surface that is wrapped around the rod again and again (i.e., the spiraling “ridges” and stairs).
- 20) Explain that when an inclined plane is wrapped around a cylinder, making a spiral, it becomes a simple machine called a *screw*. Students will most likely already know the term *screw*, so emphasize that this is a new way to identify a screw: an inclined plane wrapped around a cylinder in a spiral shape. Sometimes simple machine screws are actually called screws. Other times, simple machine screws are part of objects that have other names. Screws make work easier for humans by (1) connecting objects together, and (2) raising or lowering objects by spiraling.
- 21) Direct students to the two exercises on page 6-4 of their Engineer’s Journal. First, students should label the inclined planes hidden on the screws. Next, students should brainstorm other examples of screws. (Some examples of screws are jar lids, key rings, light bulbs, spiral staircases, clamps, and twirly stools. If you are running short on time, you may want to display three examples and fill out these charts together as a class.)
- 22) Next, hold up a knife (or instruct students to look at the photo of the knife and boat on page 6-5) and ask students to try to find the inclined planes “hidden” in these “machines.” After hearing a few student ideas, clarify that there are actually two inclined planes in wedges: the two sides of the knife and the two sides of the boat at the front/bow.
- 23) Explain that when two inclined planes are joined together to form an edge, they make up a new simple machine called a *wedge*. Wedges are often used for cutting or for doing work within very small spaces (for instance, when the wedge on a screwdriver fits into the notch on a screw).
- 24) Direct students to the two exercises on page 6-5 of their Engineer’s Journal. First, students should label the inclined planes hidden on the knife and boat. Next, students should brainstorm other examples of wedges. (Some examples of wedges are knives, axes, forks, and nails. If you are running short on time, you may want to display three examples and fill out these charts together as a class.)

Lesson 6

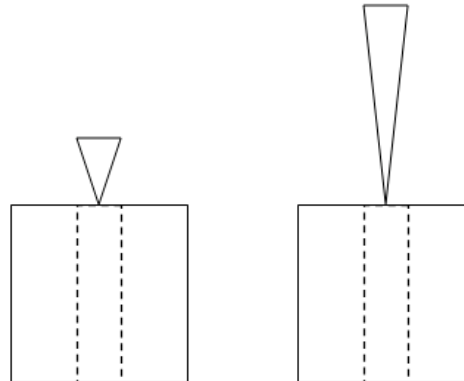
How do inclined planes, screws, and wedges work?

MAKING SENSE OF THE ACTIVITY

Note: To make the trade-off of screws clearer and relate it directly to inclined plane, you can model screws using a pencil and paper. Cut two triangles that are the same height, but different steepness. Draw over the slanted edge of the triangle in dark marker. Wrap the triangles around pencils and compare the screws. The steep plane will create a model screw with 'grooves' that have more space in between them, while the gentle plane will create a model screw with 'grooves' that have less space in between them.

25) Allot 5 minutes at the end to visit the trade-off chart and fill in the force-distance trade-offs for screws and wedges.

- The *more* wraps of an inclined plane around a cylinder to create a screw, the *further* distance to go around it but the *less* the input force.
- The *fewer* wraps of an inclined plane around a cylinder to create a screw, the *shorter* the distance to go around it but the *greater* the input force.
- To summarize force-distance trade-offs for wedges, consider a plow making a cut through the soil (as shown in the trade-off chart and image below). Less force is needed for the longer, steeper plow/wedge, but the plow needs to be pushed a longer distance to make the whole cut be as wide as the widest part of the wedge. More force is needed for the shorter, gentler plow/wedge, but the plow does not have to be pushed as long a distance to make the whole cut be as wide as the widest part of the wedge.



26) If you run out of time to complete the trade-off chart, you might do so at the beginning of the next lesson.

27) Have students use page 6-6 to make changes to their people mover design based on what they have learned about simple machines.

Lesson 7

How do pulleys work?

Suggested Time

One 60-minute session

Lesson Overview

Students will be introduced to pulley systems as a means for lifting heavy things to heights above our heads.

- Exploration question: Introduction to lifting pulley systems
- Partner work: Exploration of different pulley wheels
- Demonstration with teacher: Observing the force and distance required for fixed pulley and moveable pulley systems
- Conclusion: Wrap-up discussion

Learning Objectives

By the end of this lesson, students will be able to:

1) Explain what pulleys do to help humans:

- f) Pulleys, which are wheels with grooved edges for ropes, are used to change the direction of a pull and make it easier to lift a load.

Vocabulary

Pulley - A wheel with grooved edges for ropes that is used to change the direction of a pull and make it easier to lift a load.

Wheel - A disk or circular frame that revolves on an axle.

Fixed Pulley - Pulley that always stays in one place

Moveable Pulley - Pulley that can move along the rope it connects to.

Force - A push or a pull.

Load - The object being lifted or moved by a machine.

Spring Scale - A device for weighing that uses a hanging spring to measure the weight of an object.

Materials

For each student

- Engineer's Journal Part 7

For each pair of students

- LEGO kit
- 100-gram weight
- 45-cm (~18 inches) length of thin string marked off every 5 cm with a permanent black marker
- 4-inch piece of colored tape to use as a "flag"

Note: Unwaxed floss may be used, but it frays so durable string is recommended.

Lesson 7**How do pulleys work?*****For the class***

- 5-Newton force meter
- 0.5-liter bottle filled with water
- 2 pulleys
- 6-foot length of nylon string, 6-inch length of nylon string
- Fixed and moveable pulley demonstration set-up (see instructions below)
- Transparency of pulley exploration journal page (7-2)

Preparation

-
- **For each student pair, cut an 45-cm piece of string.** Mark off every 5 cm of the string with a permanent black marker.
 - Build the fixed and moveable pulley system for the **class demonstration:**
 - Cut a 6-foot length of string and tie one end to the full ½-liter water bottle.
 - Mark off every 6 inches of the string with a black permanent marker.
 - Cut a 6-inch length of string and tie one end to the hook portion of one of the pulleys (this will be the moveable pulley).
 - Find a high location in the classroom which can support the weight of the hanging 0.5-liter water bottle (wall hook, ceiling hook, coat rack, door, etc.).
 - Hang the other pulley over the hanging location (this will be the fixed pulley).
 - Set aside the moveable pulley, water bottle, and 5-Newton spring scale.

Instructions for Teachers***GETTING STARTED*****PART I: Introduction to Pulleys and Exploration Question (10 min)**

- 1) Explain that in today's lesson students will learn how the *pulley* simple machine helps people do work. After completing the exploration question, you will guide students in building a pulley test set-up. Using this set-up, they will explore different kinds of pulley wheels with their partners. After students complete this independent work, you will work as a class to take some force measurements for two other *pulley systems*.
- 2) State that a *pulley* is something that a rope slides over as it pulls an object, and pulleys are usually wheels with grooves in them. Pulleys are used to change the direction of a pull and make it easier to lift a load. Demonstrate using a pulley with the pulley setup to be used

Lesson 7

How do pulleys work?

later in the lesson so all students know what a pulley is.

- 3) Tell students that as a warm up to today's simple machine investigation you want them to think about how they could lift a heavy box to a place way above their head. Point out the picture in their Engineer's Journal. Read the exploration question on page 7-1: "If the person in the picture wants to lift the box up to the star, where should she put the pulley rope?" Direct students to draw where the rope should go and to explain their solution on the lines below the picture.
- 4) After 3-to-4 minutes, call on a few students to share their ideas about the placement of the pulley rope.
- 5) Conclude this initial discussion by explaining that *pulleys* are useful for changing the direction of motion – they help humans move something (e.g., a box) UP by pulling DOWN on something else (e.g., a rope). Pulleys make it easier to lift heavy things to high places. The person in the picture on page 7-1 would need to put the rope over the highest wheel in order to move the box to the star.

PART II: Exploring How Pulleys Help Us Lift (30 minutes)

- 6) Explain that there are two main science questions for today. By finding the answers to these questions, students will learn how to design a pulley for their people mover machine.
- 7) Write the two science questions on the board or chart paper. They are:
 - a. Does it matter what size pulley wheel you use?
 - b. Which makes a lifting job easier: a "fixed" pulley or a "moveable" pulley?
- 8) Students answer the first question by working with their partners on pages 7-3 and 7-4 in their journal. You will now demonstrate how to do the exercises on these pages.
- 9) First, show students how they will put together their pulley systems. Demonstrate how to put three different sizes of pulley wheels onto a beam: slide a wheel onto an axle, insert the axle into the beam, and use a bushing or two to hold the axle in place. The completed set-up should look like this:

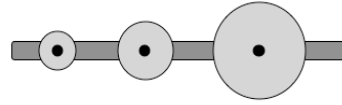
What Questions Might Students Ask During this Lesson?

- Can we use hangers or hooks (or other everyday objects that a rope can be pulled over) as pulleys? *Yes, as long as the rope can slide over the object as it pulls a load.*
- Why doesn't the size of the pulley wheel you use matter? *No matter what size the pulley, you have to pull the rope with the same force to get a load to move. The amount of friction on the a pulley wheel surface or axle does matter, but size alone does not matter.*

*ACTIVITY
EXPLANATION*

Lesson 7

How do pulleys work?



- 10) Second, show students how to “test” the pulley system, by measuring how far the weight travels and how far the string must be pulled: Use your overhead projector to display the transparency of page 7-3 (or display the PDF using a computer and LCD projector), and direct students to turn to page 7-3 in their journals.
- 11) Use your pulley-set up to demonstrate the “DO this” side of page 7-3. Then demonstrate how to fill in the “WRITE this” side of page 7-3.
- 12) Point out exercises (A) through (F) on pages 7-4 through 7-5. Students will complete these exercises with their partners after they build their own pulley systems.
- 13) Distribute an 45-cm length of string (with 5 cm markings), a 100-gram weight, a small piece of colored tape (“flag”), and a LEGO kit to each student pair.
- 14) Show students the 11 LEGO pieces they need: one 15-hole beam, 3 medium or long axles, 4 bushings, 1 big wide wheel, 1 medium thin wheel, and 1 small wide wheel. These pieces are shown on page 7-2 of their Engineer’s Journal.
- 15) Direct students to open their kits, get out the 11 pieces, and then close the kits and set them aside.
- 16) Allot 20 minutes for students to complete exercises (A) through (F) on their own. As they work, visit with pairs to facilitate their understanding.
- 17) Call students’ attention to the first science question for the day: Does it matter what size pulley wheel you use? Call on three or four students to hear their ideas. What differences, if any, did they find between the small, medium, and big wheels when they used them as pulleys?
- 18) After hearing some ideas, make sure students understand that the SIZE of a pulley wheel does NOT change the amount of force needed to lift a load, nor does it change the distance needed to lift a load.

PART III. Moveable Pulley Demonstration (20 min)

- 19) Explain that you will now do a class activity to answer the second science question for the day. Which makes lifting a load easier: a “fixed” pulley or a “moveable” pulley?
- 20) You will explore how two different kinds of pulley systems make lifting work easier. One kind is called a *fixed pulley system* because the pulley wheel stays in the same place all the time. The second kind is called a *moveable pulley system* because it has another pulley

*STUDENTS’
INDEPENDENT
ACTIVITY*

*MAKING SENSE
OF THE ACTIVITY*

*ACTIVITY
EXPLANATION*

Lesson 7**How do pulleys work?**

wheel that moves up and down with the weight.

- 21) Explain that to conduct this investigation, you will measure how much force and distance are required to lift the weight with the *fixed* pulley system and with the *moveable* pulley system. Ask students to predict: Which will take more pulling force? Which will require more pulling distance?
- 22) As it is feasible, ask students to assist you in carrying out the procedure for exploring the fixed pulley:
- Set the water bottle on the floor or a table, and pass the 6-foot string through the “fixed” pulley (the pulley that you have hung from the wall, ceiling, or other fixture). Hold on to the other end of the string.
 - Measure the *pulling distance*: Note the location where your pulling hand begins. Pull on the string until the bottle reaches the pulley. Count the inches or centimeters between where your hand is now and where it started.
 - Measure the *pulling force*: tie the force meter to the free end of the string. Pull the force meter until the bottle is halfway to the fixed pulley, and then hold your hand very still as you take the reading from the force meter.
 - Direct students to record the pulling distance and pulling force in their journals (page 7-6).



- 23) To add the moveable pulley, first remove the bottle from the 6-foot string and tie it to the 6-inch string attached to the other pulley. Second, tie one end of the 6-foot string to the fixed pulley. Third, pass the string through the moveable pulley and then back up and through the fixed pulley. Hold on to the free end of the string to keep the weight from falling. (See the picture on the following page.)

Lesson 7

How do pulleys work?

MAKING SENSE
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- 24) Repeat step #22 for the moveable pulley (finding pulling force and pulling distance). Direct students to record the data in their journals.
- 25) Direct students to complete the summary questions on page 7-6.
- 26) Now ask students for their ideas about the second science question. What differences did they find between the fixed pulley system and the moveable pulley system?
- 27) Conclude the discussion with a summary of the two different lifting situations:
 - Lifting with a fixed pulley: We pull DOWN (or any direction) with *force equal to the load*, and with *distance same as the distance moved by the load*. The pulley helps us because we can pull the string down (or sideways, or any direction) instead of pushing the load up.
 - Lifting with one moveable pulley: We pull DOWN (or any direction) with *force equal to HALF the load*, and with *distance DOUBLE the distance moved by the load*. The pulley helps us because (1) we can pull the string down (or sideways, or any direction) instead of pushing the load up, and (2) we only need to put in half the force.
- 28) Be sure to tie these conclusions into filling out the trade-off chart in the classroom and in the students' Engineering Journal.
- 29) Direct students to disassemble their pulleys and put away all LEGO pieces.
- 30) Have students use page 7-7 to make changes to their people mover design based on what they have learned about simple machines.

Lesson 8

How do gears change circular motion?

Suggested Time

One 60-minute session

Lesson Overview

Students will be introduced to the uses of gears and the ways gears can help humans.

- Introduction to the functions of gears
- Force-distance trade-offs/advantages of gears
- Using gears to change the direction of motion
- Using gears to change the speed of motion
- Design challenge: build a gear train that will spin a disk fast enough to create an optical illusion

Learning Objectives

By the end of this lesson, students will be able to:

- 1) Explain what the following simple machines do to help humans:
 - g) Gears, which are wheels with teeth around the edge, are used to turn other gears and change the direction, speed, and force of circular motion.

Vocabulary

Gear - A wheel with teeth around the edge that is used to turn other gears and change the direction, speed, and force of circular motion.

Teeth - The projections on the rim of a gear that fit between the projections on another gear.

Gear Train - A set of gears that work together to transmit a force.

Driver Gear - The gear in a gear train that provides the power to the other gears (usually gets power from a motor).

Idler - A gear or wheel that transmits motion between two other gears without change of direction or speed.

Follower Gear - The gear that moves last/outputs power in a gear train.

Motion - The process of changing place, movement.

Circular Motion - Movement in a round or circle pattern.

Direction - The way in which one may face or travel.

Force - A push or a pull.

Lesson 8**How do gears change circular motion?****Materials****For each student**

- Engineer's Journal Part 8

For each pair of students

- LEGO kit
- 'Optical Illusion' disk

For the class

- Pictures of gears
- Real gears
- Example optical illusion device

Preparation

- Distribute Engineer's Journals.
- Bring in real gears if available
- Build example gear trains and optical illusion device
- Build an "Optical Illusion Black Box" using the building instructions provided at the end of the lesson.
- Prepare an optical illusion disk for each partner group (disks included on page 8-8 of the lesson plan)

**Instructions for Teachers****GETTING STARTED****PART I: Differences between Gears and Wheels (5 min)**

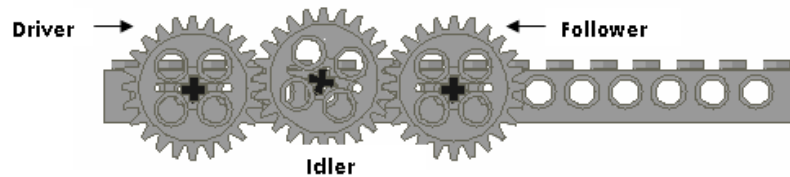
- 1) Allot 2-to-3 minutes for students to write their ideas about similarities and differences between a wheel and a gear.
- 2) Call on approximately 3 students to give answers to how gears and wheels are similar and how they are different. If no students mention that gears can make other gears turn, while wheels cannot, bring up this difference.

PART II: Introduction to Gears (5 min)

- 3) First students will need to learn a few facts about gears in order to do their exploration. Attach one gear to an axle and then slide it onto the beam. Explain that this is a gear by itself.
- 4) Add a second gear to the beam that connects directly to the first beam and explain that you now have a gear train. Gears can serve different purposes in gear trains. Explain that you have just built a *gear train*. A gear train is a series of two or more gears meshed together. Every gear train has a *driver* and a *follower*. The driver is the gear to which the force is initially applied or the first gear that is spun. The follower, or driven gear, is the final gear in the train.

Lesson 8**How do gears change circular motion?**

- 5) Add a third gear and ask students which gear is the *driver* and which gear is the *follower*. Then ask them about the middle gear. Explain that this gear also has a special name. It is called an *idler*.
- 6) During this discussion you may want to reference the example gear train picture included on page 8-1 of their Engineer's Journal.



- 7) Add a fourth gear and again get students to name the driver and follower gears. Now there are gears in the middle. Ask students what they think these gears are called. Any gears in between the driver and the follower are called *idlers*.
- 8) Before letting students build their own gear trains, it is important to show them that this method of building the gear trains (with only gears and axles), while quick, is not the most stable. Tell them that it is important to keep the gears face up and the axles pointed down. This will let them make the observations they need to make to learn how gears work for creating their own optical illusion device.
- 9) Demonstrate how if they tip the beam upside down, all the gears will fall out.

PART III: Force-Distance Trade-off of Gears (15 minutes)

- 10) Explain to students that sometimes gears are used to move a load or weight. Their first gear train exploration will look at the advantages of using different gears as the driver to move a load.
- 11) Instruct students to turn to page 8-2 in their Engineer's Journal where they will build the first gear train with you.
- 12) Pass out LEGO kits if they are not already out. Instruct students to take out the pieces on page 8-2 and then put their kits on the floor.
- 13) Walk students through the steps for building their first gear train, shown on the next page and included in their Engineer's Journal.

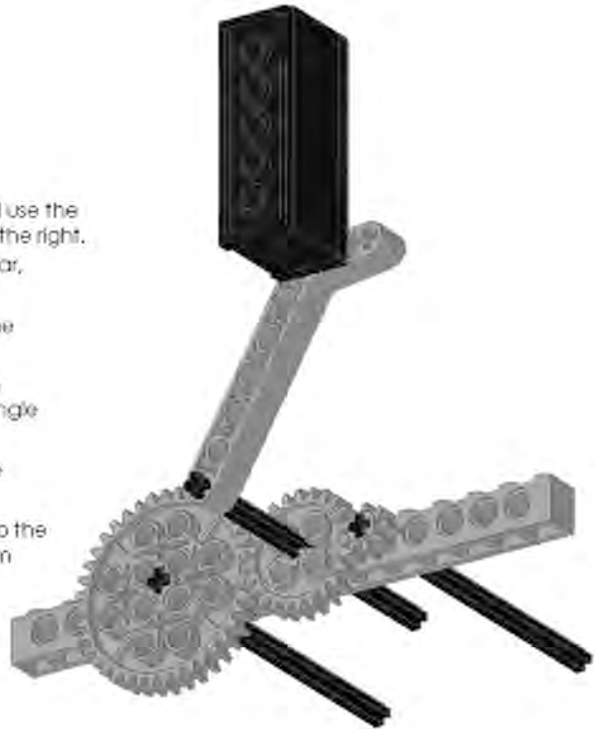
**ACTIVITY
EXPLANATION**

Lesson 8

How do gears change circular motion?

STEP 2. Follow the instructions and use the picture to build the gear train on the right.

- 1) Connect one axle to each gear, making three gear 'lollipops'
- 2) Slide the gear lollipops onto the beam in the order shown
- 3) Make the axle on the medium gear stick out further so the angle beam can connect to it
- 4) Attach the angle beam to the medium gear axle
- 5) Connect the weighted brick to the two holes in the slanted beam



- 14) As students build the gear train remind them that they are trying to see the advantages of using different gears to turn a load.
- 15) Once they have the gear train built they need to take turns testing the large and small gear as the driver in order to determine the advantage of using each gear.
- 16) Once they have tested both gears they should answer the questions at the bottom of 8-2 concerning the advantages of each gear. The advantage of the small gear is that it requires less force to turn the weight or load. The advantage of the large gear is that it requires less distance or fewer turns to turn the weight or load.
- 17) As students finish direct them to move onto pages 8-3 and 8-4 to learn about direction and speed of gears. Once all students have completed the force-distance page, or at a good stopping point, pause the class so that you can introduce the optical illusion device challenge.

What Questions Might Students Ask During this Lesson?

- Can there be more than one follower? *If the first gear turned (the driver) is in the middle of gears, gears on BOTH ends of the gear train are followers.*
- How do we attach the weight? *The top of the weight (with studs) sticks into two of the holes in the angle beam. It does not fit into the angle beam hole that is an x, so make sure you are attaching it to two holes.*
- How can I see what direction or how fast the gears are turning? *Turning the gear train slower makes it easier to see the direction and speed. Putting a connector peg in the gear can also help, especially with speed.*

Lesson 8**How do gears change circular motion?***ACTIVITY
EXPLANATION*PART III: Optical Illusion Introduction (5 minutes)




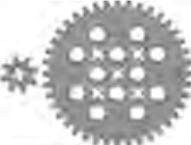


- 18) Make sure your Optical Illusion Black Box is working properly. Inside your box is a gear train in which the *follower gear* spins 25 times faster than the *driver gear*. Protruding out from your box is one axle attached to the driver gear, and one axle attached to the follower gear. A handle is attached to the driver's axle. A patterned disk (called a Benham's disk) is attached to the follower's axle. When you turn the driver handle slowly, the follower disk spins very quickly and creates an optical illusion. Because the gear train is hidden inside the box, your students can see only two things: the handle that you are rotating slowly, and the disk that is spinning quickly. A good way to hide your device is to wrap tin foil or paper around the gear train so that it can be easily removed if needed and not catch in the gears when they are turned.
- 19) Announce that you are about to show a special "Black Box" device that creates an optical illusion. It is called a "black box" because students cannot see what is happening inside it. Ask students what simple machine they think is inside the black box. They should readily say gears since they have started learning about them.
- 20) As you turn the handle, make sure students notice that you are turning your handle very slowly, but the optical illusion is spinning very quickly. Explain that by the end of the next two journal pages they will have an idea about how to build their own gear train to create an optical illusion. Explain that they will receive an optical illusion disk and get to build an optical illusion device only if they have completed both pages 8-3 and 8-4 in their journals.

*STUDENTS'
INDEPENDENT
ACTIVITY*PART IV: Using Gears to Change Directions and Speed (20 min)

- 21) On pages 8-3 and 8-4 in their Engineers Journal, students will learn about the three main uses of gears by building different gear trains and answering questions about them. The three main uses of gears are speeding up motion, slowing down motion, and changing the direction of motion. For ease, the gear trains and questions are included on the next page. The correct answers to questions are bolded.

Lesson 8

How do gears change circular motion?

Gear Train	Circle the answer to complete the sentence.
	When the first gear turns right, the second gear turns: left right The gears turn at _____ speeds. the same different
	When the first gear turns right, the second gear turns: left right the third gear turns: left right
	The big gear turns _____ than the small gear. faster slower
	The small gear turns _____ than the big gear. faster slower
	The big gears turn at _____ speeds. the same different
	The fastest gear is the smallest medium largest The slowest gear is the: smallest medium largest

- 22) Direct students to take turns building and that they will need to work together to make the observations. Tell students there are not enough pieces for them to each build their own gear trains.
- 23) Mention to students that adding connector pegs to the gears can help them see the direction and speed gears spin at. If they are having trouble they should first add connector pegs and then ask the teacher for help.
- 24) Walk about the room and ask students questions about their gear trains. Monitor whether students understand that gears next to each other turn in different directions, while gears one away from each other turn in the same direction. Also, monitor whether students understand that smaller gears turn faster than larger gears because they are making more turns.
- 25) Check that students have filled out all the gear train observation pages and ask them a question about gear trains before giving them an optical illusion disk. Some students will not have enough time to get to the optical illusion device.

Lesson 8**How do gears change circular motion?***STUDENTS'
INDEPENDENT
ACTIVITY**MAKING SENSE
OF THE ACTIVITY*PART V: Optical Illusion Device (15 min)

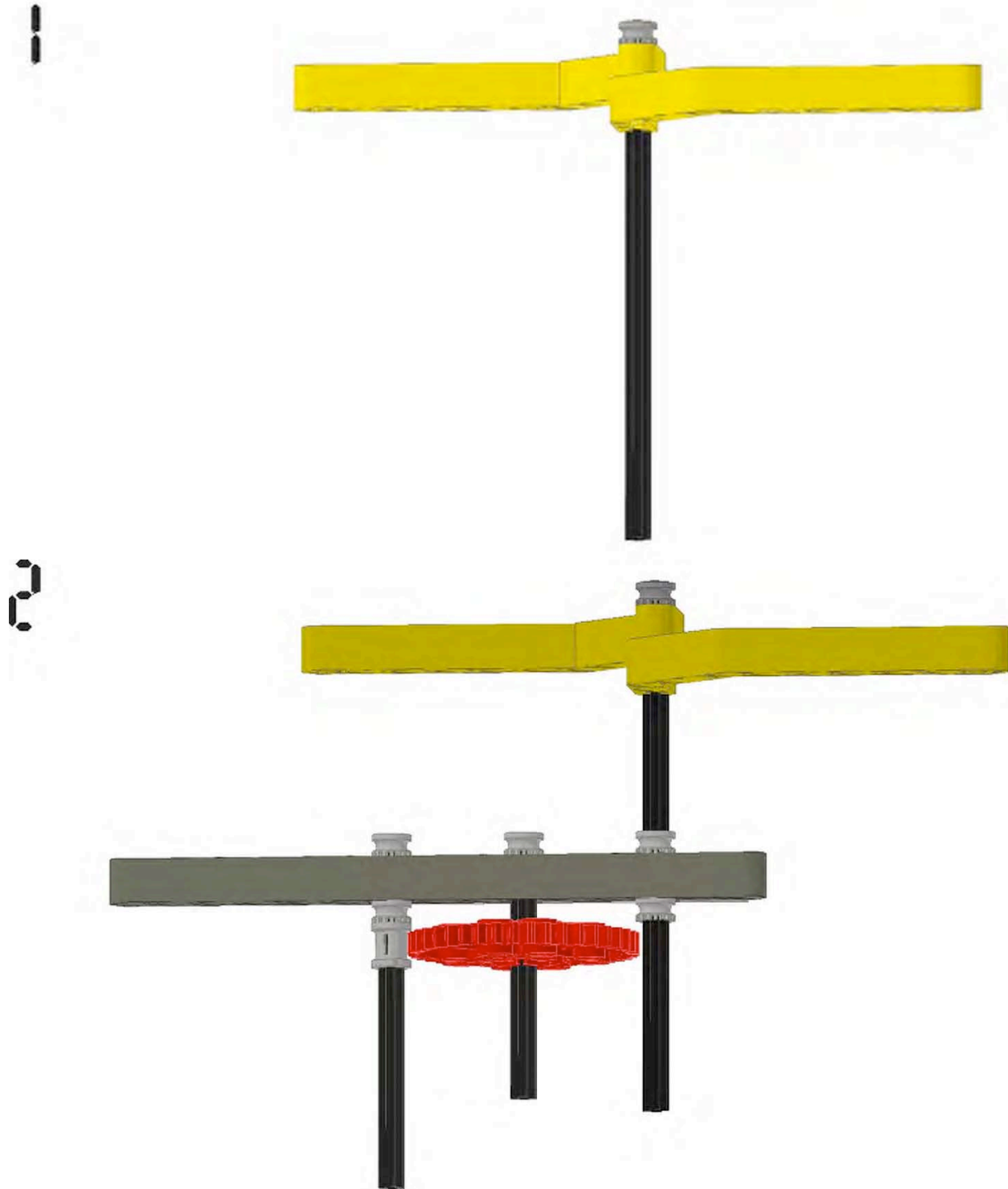
- 26) Point out to students the hint on the bottom of the optical illusion device page 8-5 about using two gears on one axle. Reinforce that the gear train should fill the whole beam, the disk should be on the follower, and the follower should spin as fast as possible. Remind students to diagram their optical illusion gear trains in their journals.
- 27) If some students finish the optical illusion task quickly, challenge them to compute exactly how much faster the follower is spinning than the driver (2 times as fast? 5 times as fast? 25 times as fast?). Then challenge them to change their device so the follower turns even faster (you might even specify a certain ratio: with the gears provided in the NXT kits, ratios of 9:1, 25:1, 125:1 are achievable with compound gear trains).
- 28) After 10 minutes of work on the speed-changing gear trains, inform students that they have only 5 minutes remaining to finish.
- 29) Disassemble gear trains and clean up.

Part IV: Wrap-Up Discussion and Clean-Up (2 min)

- 30) Summarize the main points of today's activities:
- Gears are simple machines that help humans by changing the direction or speed of something that is spinning.
 - Neighboring gears always spin in opposite directions, while gears with another gear in between them spin in the same direction.
 - If gears are the same size, they spin at the same speed. If they are different sizes, the smaller gear spins faster than the bigger gear.
 - Small gears take less force and more distance to spin a load, while large gears take more force and less distance to spin a load.
- 31) It may be easiest to review the questions with students to summarize the day's activities. Be sure to fill out the trade-off chart as well.
- 32) If time allows, demonstrate hooking the gear train up to a motor and using the motor to provide the effort or power. Explain that the motor is a complex machine, though we cannot see the inside. Motors can be made to go fast or slow with gear trains.
- 33) On page 4-5 instruct students to make changes to their people mover design based on what they have learned about simple machines.



Building Instructions for Optical Illusion Gear Train

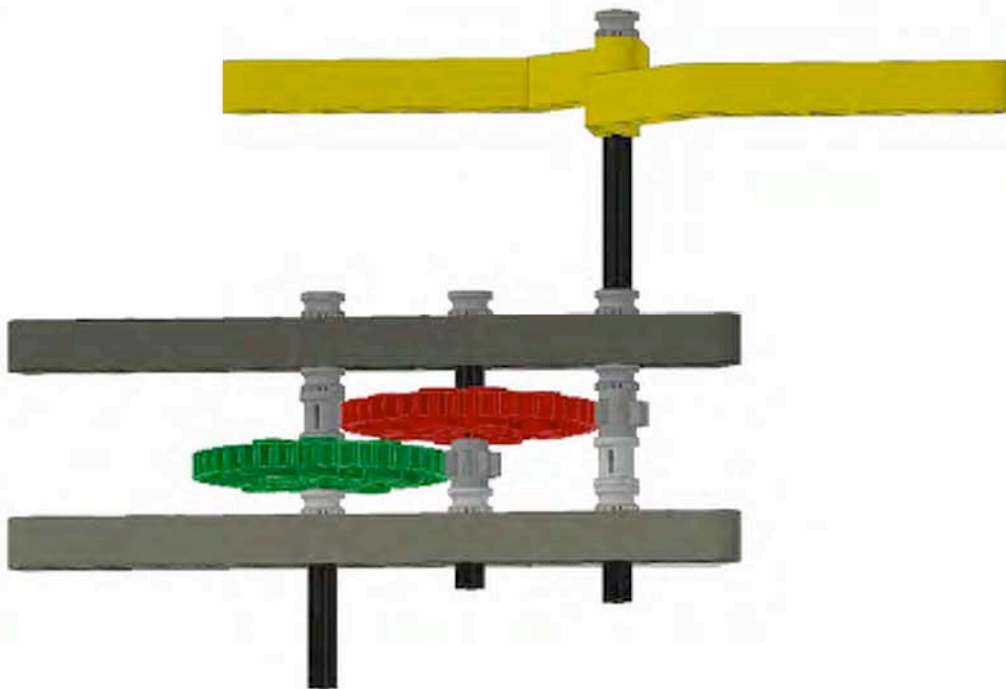


Building Instructions for Optical Illusion Gear Train

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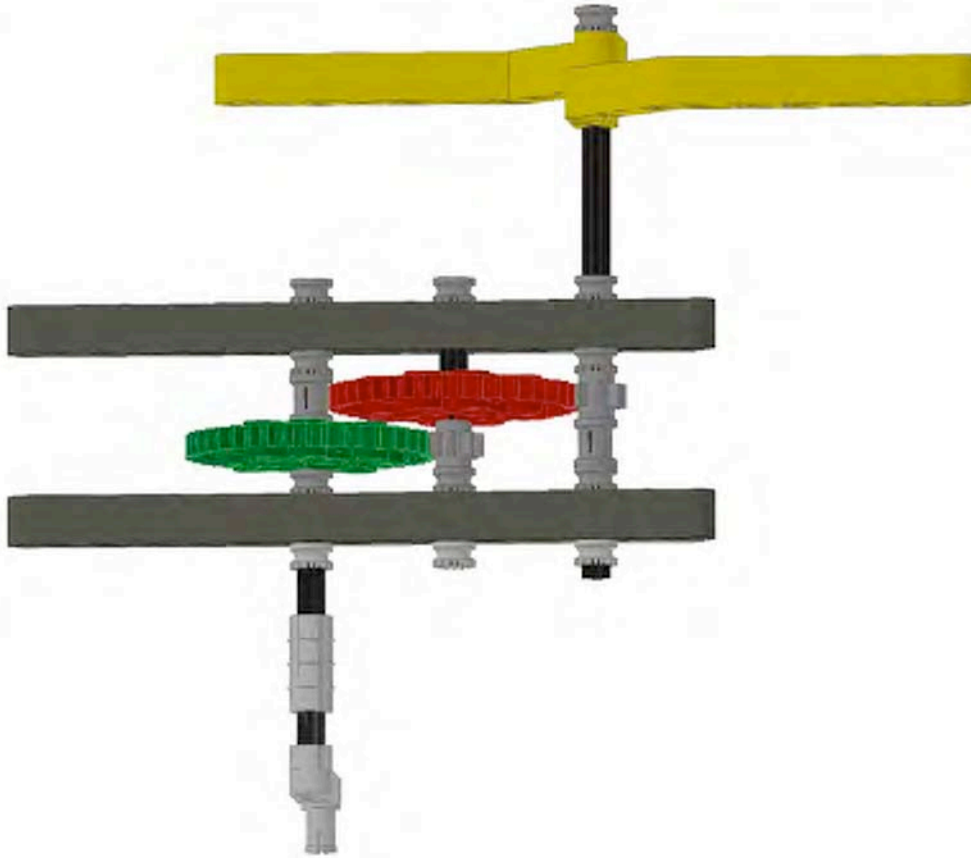


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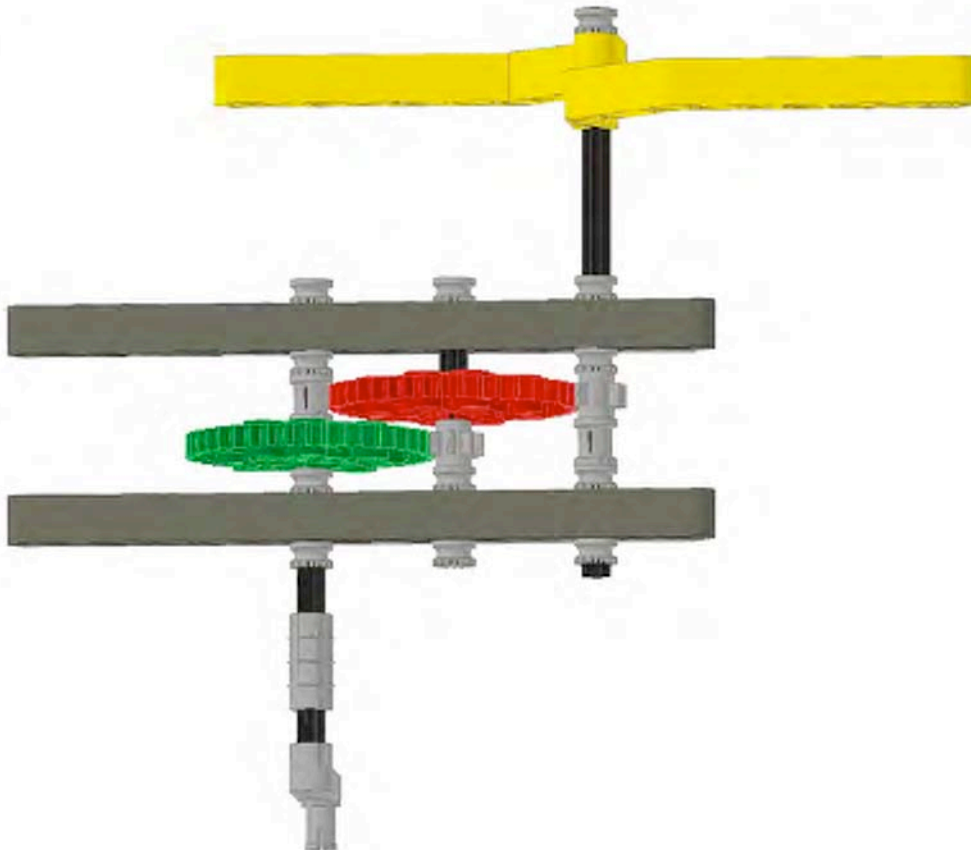


Building Instructions for Optical Illusion Gear Train

5



6



Lesson 9

How can we find simple machines in complex machines?

Suggested Time

One 60-minute session

Lesson Overview

Students will be introduced to how simple machines can be put together to make complex machines.

- Identify the simple machines in a complex machine
- Review Tradeoffs
- Preliminary design of people mover

Learning Objectives

By the end of this lesson, students will be able to:

3) Identify simple machines within complex machines.

Vocabulary

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Simple Machine - Anything that has few parts and makes it easier to do a task.

Complex Machine - A combination of two or more simple machines.

Materials

For each student

- Engineer's Journal Part 9

For the class

- Transparencies or print-outs of other complex machines
- Physical objects of some of the complex machines included in their journal (scissors, hand-crank pencil sharpener, can opener, crane)

Preparation

- Distribute Engineer's Journals.
- Gather some physical objects that are complex machines

Lesson 9**How can we find simple machines in complex machines?*****Instructions for
Teachers******GETTING
STARTED******ACTIVITY
EXPLANATION******STUDENTS'
INDEPENDENT
ACTIVITY*****PART I: What is a Complex Machine? (10 min)**

- 1) Explain that now that they have learned all seven simple machines, they will focus on complex machines.
- 2) Ask students what the names of the seven simple machines are and write them on the board as they are stated. Allow two minutes for students to name all the simple machines.
- 3) Ask students to turn to page 9-1 in their Engineer's Journal and read the exploration question aloud.
- 4) Ask students to brainstorm what the difference is between a simple and a complex machine. They should discuss their ideas with their partner and then write their ideas in their Engineer's Journal. After 2-to-3 minutes of brainstorming, discuss student ideas aloud.

PART II: Simple Machines in Complex Machines (20 min)

- 5) Explain that it is important to break down complex machines into simple machines when modeling them. It gives you more information about how a machine works.
- 6) Explain that they will practice identifying simple machines in complex machines, first as a class and then individually.
- 7) Have students turn to page 9-2 in their Engineer's Journal. Use the overhead projector to display the first two complex machines, scissors and can openers, and discuss what simple machines are part of the complex machines. It may be useful to give students a minute to independently look at the complex machines and identify the simple machines before discussing it as a class.
- 8) For the last two complex machines, a manual pencil sharpener and a crane, allow students to work individually or in pairs to identify the simple machines.

What Questions Might Students Ask During this Lesson?

- Is a cup (or other object not typically a machine) a complex machine? *Ask students if the object helps them if they only think about the object in terms of force and distance.*
- We looked at some of the complex machines as simple machines. Why are they complex now? *All complex machines include at least two simple machines. Sometimes we use complex machines as examples of simple machines because it is easy to see the simple machine within.*
- What version of (fill in simple machine type) should we use? *Look at the trade-off chart and decide if less force or less distance is more important.*
- If a complex machine has screws or wedges, doesn't that mean it also has inclined planes? *Since there are inclined planes 'hidden' in screws and wedges, the complex machine would also include inclined planes.*
- Doesn't everything include screws? *Not everything includes screws, though they are part of many machines.*

Lesson 9**How can we find simple machines in complex machines?***MAKING SENSE
OF THE ACTIVITY*

- 9) Once most students are done, go over what simple machines are in the complex machines as a class. Scissors include a lever and wedges. Can openers include a wheel-and-axle, lever, gears, and wedges. Some can openers also include screws and people might include inclined planes due to the presence of wedges and screws. Manual pencil sharpeners include a wheel-and-axle, screws, and wedges. Some manual pencils also include gears and people might include inclined planes due to the presence of wedges and screws. Cranes include pulleys, levers, and screws. Some cranes also include gears and wheel-and-axles on the inside.
- 10) Ask students if they came up with any strategies for finding simple machines in complex machines. For example, they might look for every simple machine one by one or look for rotation points and determine what simple machine is using the rotation point.

PART II: Simple Machine Trade-Offs (20 min)

- 11) Explain to students that they are now in the last stage of researching solutions so that they can create their own model people mover to show the airport staff. The last thing they need to do is review all the force-distance trade-offs of the simple machines.
- 12) Have students turn to the Trade-Off Chart in their Engineer's Journal and step through the trade-offs of each simple machine. You might give students 3 minutes to come up with a way to describe one of the trade-offs and then have them explain each simple machine trade-off to their peers. An example of a completed trade-offs chart is included on the next page.


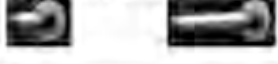

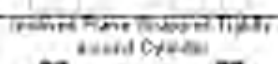



PART III: People Mover Design (20 min)

- 13) Review the tasks that the students must carry out to complete the challenge: (1) brainstorm and sketch ideas independently, (2) share ideas with partner, (3) choose the best idea, and (4) if there is time, begin to build.
- 14) If people are stumped remind them how they did an initial design and brainstormed ideas of machines that lift people up and move people across surfaces in the first part of their journal. Remind them that these ideas might be useful for their final design.
- 15) Give students 5 minutes to brainstorm and sketch one idea independently. After this individual work, tell them to share their ideas with their partner and combine their ideas into one sketch. This sketch will be the basis of their final design.
- 16) You might want to tell students that they will not get the LEGO kits until their group has shown the teacher their completed design ideas.

Lesson 9

How can we find simple machines in complex machines?

17) If students finish brainstorming, allow them to begin work with their partners on designing their complex machines.

How Can We Design Simple Machines To Be Most Helpful For Doing Work?		
Simple Machine	Design "Rules of Thumb"	
	How to Put in Less Force	Tradeoff for Putting in Less Force
Lever	Move Fulcrum Closer to Load 	Have to Push Lever for a Longer Distance AND Lever May be High in the Air When Pushing It
Wheel and Axle System	Bigger Lower Wheel or Handle 	Larger Rotation Distance Drive
Wedge	Longer Thinner Steeper Wedge 	Have to Push Wedge for Longer Distance to Make Same Round Cut
Screw	Inclined Plane (Support Tightly around Cylinder) 	Have to Tighten Screws (More Rotations) to Get the Screws In
Inclined Plane	Use Greater Inclined Plane 	Inclined Plane will be Longer
Pulley	Use Movable Pulley 	Movable Pulley Requires the Rope to Pull in Twice the Distance to Move Something to the Same Height
Gear	Use Smaller Gear as Driver 	Have to Turn the Small Gear More times to Get the Follower to Go the Same Distance in a Full Cycle

Lesson 10

What simple machines can be used to create a model people mover?

Suggested Time

One 60-minute session

Lesson Overview

Students will construct their LEGO-person-moving complex machines.

- Review of instructions for constructing and diagramming complex machines.
- Partner work to construct and test machines.
- Diagramming of final machines.

Learning Objectives

By the end of this lesson, students will be able to:

- 3) Identify simple machines within complex machines.
- 4) Choose the best simple machines to incorporate into a design to address a problem.

Vocabulary

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Simple Machine - Anything that has few parts and makes it easier to do a task.

Complex Machine - A combination of two or more simple machines.

Materials

For each student

- Engineer's Journal Part 10

For each student pair

- LEGO NXT kit

For the class

- Extra materials for machine construction:
 - String or dental floss
 - Rubber bands
 - Scissors

Preparation

- Distribute Engineer's Journals and NXT kits.

What Questions Might Students Ask During this Lesson?

- Do we all have to use the same simple machines for our people mover? *No, there are many ways to put several simple machines together to make a model people mover.*
- Can we move the LEGO person more than 6 inches up and 18 inches across? *Yes, as long as the LEGO person ends up only 6 inches up and 18 inches across from its start.*
- Do we need to say yes to everything on the rubric? *That is the goal.*

Lesson 10**What simple machines can be used to create a model people mover?**

*Instructions for
Teachers**GETTING
STARTED**STUDENTS'
INDEPENDENT
ACTIVITY*

PART I: Review of Today's Tasks (10 min)

- 1) Explain to students that today their task is to finish designing and building their LEGO-person-moving complex machines. Remind them that this challenge models the real-world problem of moving human beings around from place to place.
- 2) Review with students the instructions for constructing and testing their machines. Emphasize the importance of testing, re-designing, and re-building.
- 3) Review the rubric for their final machines, emphasizing requirements.
- 4) Review the instructions for diagramming the final machines. Explain that engineering diagrams are neater and more detailed than brainstorming sketches. Students should label the LEGO parts used to build their machines, and they should label the simple machines within their complex machine.

PART II: Building, Testing, and Diagramming (50 min)

- 5) Allot the rest of the class session for building, testing, and diagramming.
- 6) If some students finish early, you might ask two pairs to try to put their machines together to move a LEGO person up and over TWO NXT kits or request a more detailed or larger diagram. You could also challenge them to add a fourth simple machine or ask for further elaboration on the rubric's challenge question.

Rubric for People Mover

	<p>Modelers: Circle your self-evaluation below.</p>	<p>Jobs of your simple machines: (Reminder: the seven simple machines are levers, wheels-and-axles, inclined planes, screws, wedges, gears, and pulleys)</p>
<p>Does our model use three simple machines?</p>	<p>Yes No (1 pt) (0 pt)</p>	<p>Name your first simple machine: _____ (1) Where is its input force? _____</p>
<p>Once the LEGO person is attached to the machine we do not have to touch it again.</p>	<p>Yes No (1 pt) (0 pt)</p>	<p>(2) Where is its output force? _____</p>
<p>Our complex machine only needs to be touched once for it to run.</p>	<p>Yes No (1 pt) (0 pt)</p>	<p>----- Name your second simple machine: _____</p>
<p>Our model can move the LEGO man up and across the NXT box.</p>	<p>Yes No (1 pt) (0 pt)</p>	<p>(1) Where is its input force? _____</p>
<p>Our model can move the LEGO man and weight baggage up and across the NXT box.</p>	<p>Yes No (1 pt) (0 pt)</p>	<p>(2) Where is its output force? _____</p>
<p><i>Challenge 1:</i> Our model can move the LEGO man up and across the NXT box in less than 10 seconds.</p>	<p>Yes No (1 pt) (0 pt)</p>	<p>Name your third simple machine: _____ (1) Where is its input force? _____</p>
<p><i>Challenge 2:</i> Our model can move the LEGO man and weight up and across the NXT box in less than 10 seconds.</p>	<p>Yes No (1 pt) (0 pt)</p>	<p>(2) Where is its output force? _____</p>

Lesson 11

How do simple machines help us?

Suggested Time

One 60-minute session

Lesson Overview

Students will present their complex machines to other students and review other students' machines. A culminating class discussion will help students reflect on their learning about simple and complex machines.

- Review of instructions for presenting and reviewing machines.
- Students walk around the classroom to review other machines and record their observations.
- Final class discussion.

Learning Objectives

By the end of this lesson, students will be able to:

- 3) Identify simple machines within complex machines.
- 4) Choose the best simple machines to incorporate into a design to address a problem.

Vocabulary

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Simple Machine - Anything that has few parts and makes it easier to do a task.

Complex Machine - A combination of two or more simple machines.

Materials

For each student

- Engineer's Journal Part 11

For each student pair

- LEGO NXT kit

For the class

- Extra materials for machine construction:
 - String or dental floss
 - Rubber bands
 - Scissors

Preparation

- Distribute Engineer's Journals and NXT kits.
- Decide how to create groups with two pairs.

What Questions Might Students Ask During this Lesson?

- If we used different simple machines than someone else are we wrong? *No, there are many ways to put several simple machines together to make a model people mover.*
- Can't all the simple machines be used to change (one of the categories in last chart)? *Lets go through each simple machine and see if we can scientifically explain why each simple machine would or would not belong.*

Lesson 11

How do simple machines help us?

Instructions for Teachers

GETTING STARTED

STUDENTS' INDEPENDENT ACTIVITY

MAKING SENSE OF THE ACTIVITY

PART I: Review of Today's Tasks (5 min)

- 1) Explain to students that today their task is to present their complex machine to another pair of students, and also review another group's machine.
- 2) Review with students the instructions for the machine review session. Each pair will work with one other pair. They will take turns watching a demonstration of the other machine and recording (1) what simple machines are used to move the person UP, and (2) what simple machines are used to move the person ACROSS. Form student pairs into groups with two pairs each.
- 3) Explain that they will have 10 minutes total for the review session. First, one pair will share. Then, the other pair will share. Each pair should take no more than 5 minutes to examine the other pair's machine.
- 4) Review the machine observation format in the students' journals.
- 5) Before the session begins, students should move their machines to a location away from their desks.

PART II: Students' Review of Complex Machines (10 min)

- 6) Allot 10 minutes for the review session. You may want to ring a bell or flick the lights after 5 minutes to indicate that pairs should switch roles.

PART III: Final Class Discussion (30 min)

- 7) Ask students to return to their desks so that you can have a class discussion, or to come to the class meeting area. They should have with them only their journals and nothing else.
- 8) Create a chart like the one shown below with a column for each of the two pieces of information that students were asked to record about the LEGO-person-moving machines. Ask each student pair to help you fill in the two columns for the other pair in their group.

Simple machines that help move the LEGO person UP :	Simple machines that help move the LEGO person ACROSS :

- 9) After each pair has reported on one other pair's machine, explain that you are now going to move beyond the UP-movement and ACROSS-movements to a discussion of other ways that simple machines help make work easier.

Lesson 11

How do simple machines help us?

10) Conclude by working as a class to fill in the following chart.

Simple machines that help to split or cut :	Simple machines that help to change direction :	Simple machines that help to change speed :	Simple machines that help to change amount of needed effort :

Note: There is no one "correct" way to complete this chart. What is important is that students are able to explain their reasoning for the placement of the simple machines.

11) Gather students ideas about which simple machines belong in each column. Ask students to explain their reasoning scientifically.

12) Point out that most simple machines fit into **more than one category**. The most common categorization is:

- Split or Cut: wedge, screw
- Change Direction: gear, lever, pulley
- Change Speed: gear, pulley, inclined plane
- Change Effort: all (lever, wheel-and-axle, inclined plane, screw, wedge, pulley, gear)

13) Theoretically, each simple machine could be incorporated into a device that carries out any of the four tasks listed in the chart. Consequently, you should expect students to disagree about which simple machines belong in each category. When disagreements occur, facilitate a discussion about the simple machines in question. Ask students to explain the evidence they are using to relate simple machines to tasks.

Section 2: Student Handouts for All Lessons

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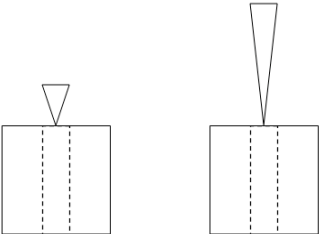



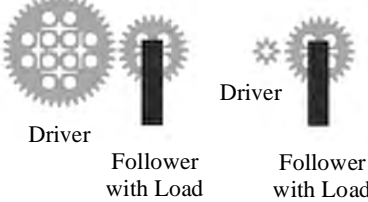
Name: _____

Design a People Mover Engineer's Journal

YOUR GRAND ENGINEERING DESIGN CHALLENGE:

Make a COMPLEX machine that can move a LEGO person UP 6 inches and OVER 18 inches (to the top of an NXT kit, and from one end of the kit to the other). Your complex machine must use at least three simple machines. Once you turn your machine on, you may not touch your LEGO person until the end of the UP-and-OVER move.

How Can We Design Simple Machines To Be Most Helpful For Doing Work?

Simple Machine	Design “Rules of Thumb”	
	How to Put in Less Force	Tradeoff for Putting in Less Force
Lever		
Wheel-and-Axle System		
Wedge		
Screw		
Inclined Plane		
Pulley		
Gear		

Name:

What machines help people move?

SIMPLE MACHINES – PART 1

TODAY'S EXPLORATION QUESTION: Brainstorm ideas for machines that move people.

(1) List at least three real-world machines that are used to lift humans UP (vertically) from one place to another. What are their pluses and minuses (trade-offs)?

3 machines that move humans UP:	One "plus" of using each machine:	One "minus" of using machine:
1.		
2.		
3.		

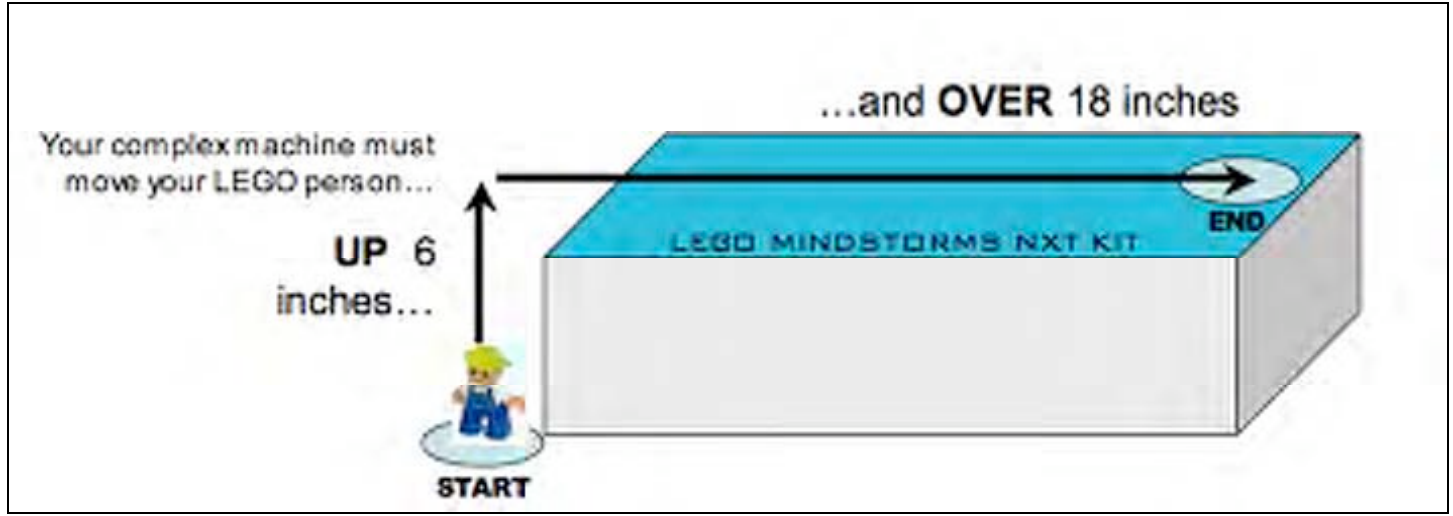
(2) List at least three real-world machines that are used to move humans OVER (horizontally) from one place to another. What are their pluses and minuses (trade-offs)?

3 machines that move humans OVER:	One "plus" of using each machine:	One "minus" of using machine:
1.		
2.		
3.		

Name: _____

What machines help people move? _____

FINAL DESIGN CHALLENGE: Make a **COMPLEX** machine that can move a LEGO person **UP 6 inches** and **OVER 18 inches** (to the top of an NXT kit, and from one end of the kit to the other). Your complex machine must use at least three simple machines. *Once you turn your machine on, you may not touch your LEGO person until the end of the UP-and-OVER move.*



Name: _____

What machines help people move?

INITIAL DESIGN: Brainstorm one idea for machines that will move your LEGO person UP and OVER. Remember that you may only touch the LEGO person yourself before you turn your machine on.

Sketch of Idea:

Written explanation of Idea:

PITCH: Come up with a pitch to convince airport staff that your idea for a people mover is the best one. Write at least two sentences to make your pitch.

Name:

What are the seven simple machines?

SIMPLE MACHINES – PART 2

TODAY'S EXPLORATION QUESTIONS: *(Draw what you think, label your drawing, and explain it on the lines below.)*

(1) You frequently use machines in your daily life. What are two examples of machines?

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(2) Pick one of your example machines. What job do you think it does? (What problem do you think it solves?)

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(3) How do you think the machine works? (What do you think is inside the machine that makes it do its job?)

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Name: _____

What are the seven simple machines?

Simple Machines: Fill in *at least one object*, its use, and predict its name from the list.
Gear Inclined Plane Lever Pulley Screw Wedge Wheel-and-Axle

The object is:	The object is used to:	These objects are all examples of the simple machine called a:
(Station 1) Screw Spiral Staircase Picture Light bulb End	Attach things together Go up in a winding direction Attach light bulb to socket	My Predicted Name: Screw Scientific Name: Screw
(Station 2)		My Predicted Name: Scientific Name:
(Station 3)		My Predicted Name: Scientific Name:
(Station 4)		My Predicted Name: Scientific Name:

Name: _____

What are the seven simple machines?

Simple Machines: Fill in *at least one object*, its use, and predict its name from the list.

Gear Inclined Plane Lever Pulley Screw Wedge Wheel-and-Axle

The objects are:	These objects are used to:	These objects are all examples of the simple machine called a:
(Station 5)		My Predicted Name: Scientific Name:
(Station 6)		My Predicted Name: Scientific Name:
(Station 7)		My Predicted Name: Scientific Name:

Name:

What happens when we change a lever's rotation point?

SIMPLE MACHINES – PART 3

TODAY'S EXPLORATION QUESTION:

Your teacher is trying to get a nail out of a board with a hammer.

(1) Do you think your teacher will be able to remove the nail by pulling straight up on the hammer? Circle one.

Yes

No

Why or why not?



(2) Is there a way to use the hammer that would work better or worse to get the nail out?

(Use this space to draw your idea.)

Name: _____

What happens when we change a lever's rotation point?

FORCE, DISTANCE, AND LOAD

On the picture of the hammer removing the nail below, draw an arrow to and label:

- 1) Where the force is applied
- 2) What distance the force moves through
- 3) Where the load is



LEVER FEATURES

What are the four features of levers?

- 1) _____
- 2) _____
- 3) _____
- 4) _____

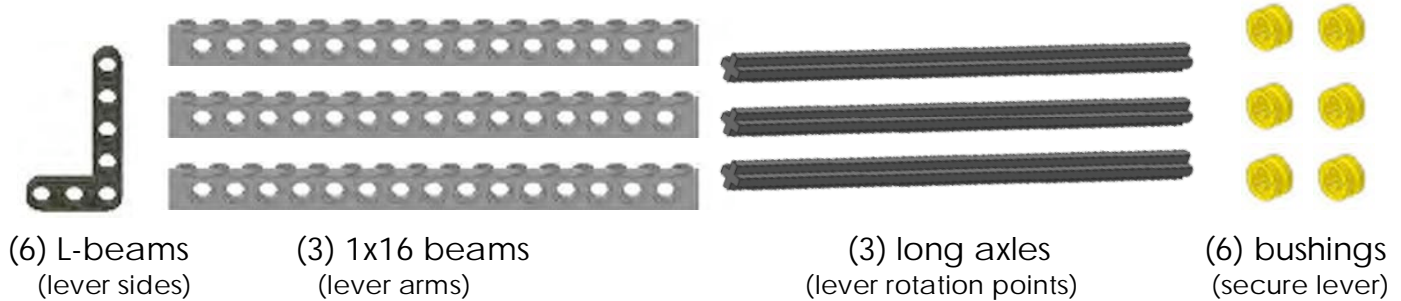
Name: _____

What happens when we change a lever's rotation point?

TODAY'S SCIENCE EXPLORATION: Build and make observations of a weight-lifting lever.

BUILDING INSTRUCTIONS: WEIGHT-LIFTING LEVERS

STEP 1. Find these LEGO pieces:



STEP 2. Read these directions for building a lifting lever:

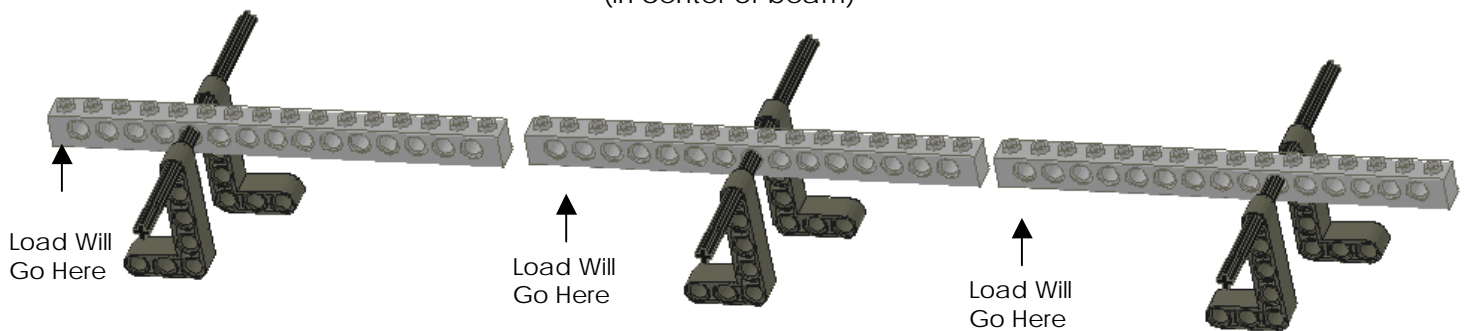
- Slide one axle first through the top hole in an L-beam, second through a hole in a 1x16 beam, and third through the top hole in another L-beam. This axle is the lever's *rotation point*.
- Make sure the short ends of the L-beams are pointing in opposite directions.
- Building Tip: Make sure that the studs on the 1x16 beams are facing *up*.

STEP 3. Build three lifting levers with different rotation points. The rotation points should be:

(A) 5 holes from left end of beam

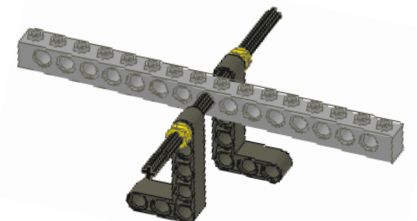
(B) 7 holes from left end of beam
(in center of beam)

(C) 9 holes from left end of beam



STEP 4. Add bushings as shown to make your lifting levers sturdier.

STEP 5. Tape all levers to the top of the desk.

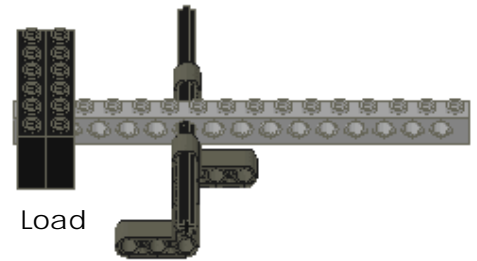


Name: _____

What happens when we change a lever's rotation point?

INVESTIGATION INSTRUCTIONS: WEIGHT-LIFTING LEVERS

STEP 1. Attach a weighted brick to the left end of the first lever arm. This brick is your load. →



STEP 2. Push with your pinky finger on the other end of the beam. Feel how much force you have to use to lift the load.

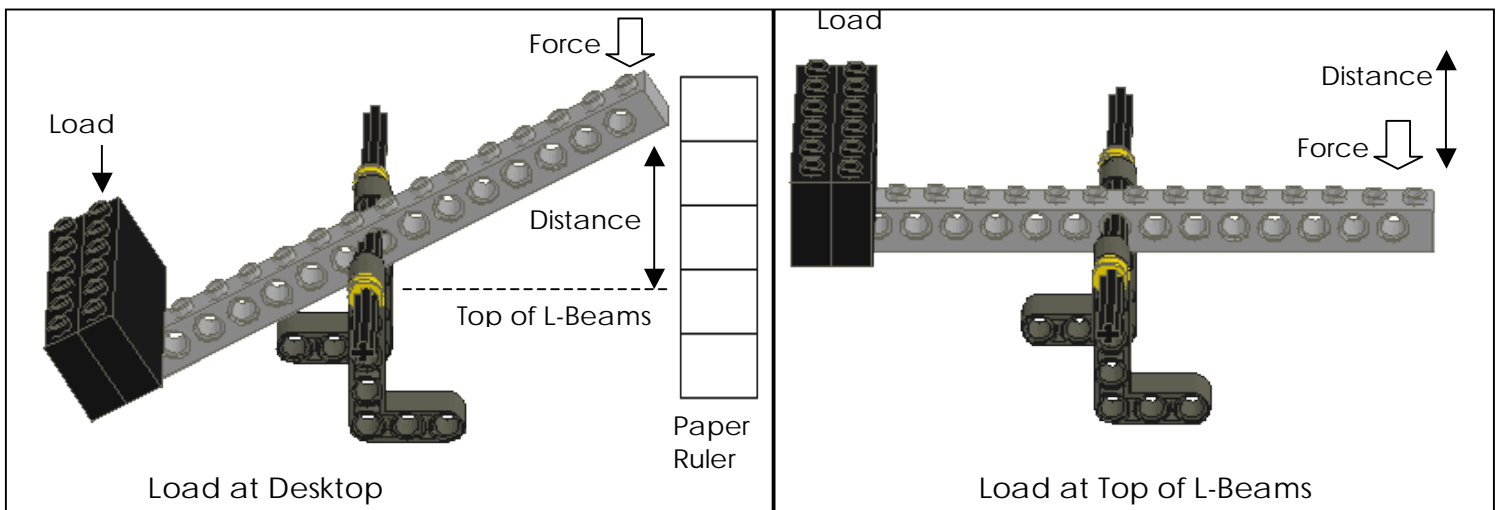
STEP 3. Move the load (brick) to the left end of the second lever arm. Feel how much force it takes to lift the load. Repeat this step with the third lever arm.

STEP 4. Record your observations of force in the chart. (One lever will take a lot of force, one lever will take a medium amount of force, and one lever will take a little force.)

STEP 5. Now you will measure the distance you move the *right* end of each lever to lift the load to *the same height as the top of the L-beams*.

STEP 6. Use the paper ruler to measure how far you push the *right* end of the beam to lift the load to *the same height as the top of the L-beams*. Repeat this step for all three levers. Round to the nearest centimeter.

STEP 7. Record your observations of distance in the chart. (Move the load between the different levers to record each distance.)

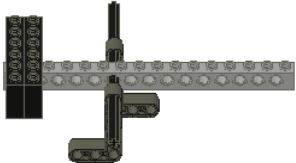
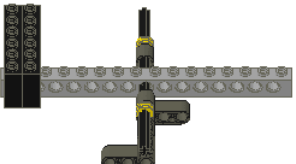
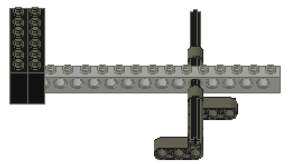


Distance = how far you have to push the end opposite the load to lift the load from the desktop to the top of the L-beams

Name:

What happens when we change a lever's rotation point?

Record your observations about the force and distance needed to lift the load for each lever.

LIFTING LEVER OBSERVATIONS	LEVERS	How much force do you have to put in? (A little, a medium amount, or a lot?)	What is the distance you have to push to lift the load to the same height as the top of the L-beams? (Use the paper ruler to measure. Round to the nearest centimeter.)
Lever #1 (Rotation point near load)			
Lever #2 (Rotation point in the middle)			
Lever #3 (Rotation point far from load)			

Name:

What are other types of levers?

SIMPLE MACHINES – PART 4

LEVER TRADE-OFFS:

(1) If you want to put in the least force to lift the load, where should the rotation point be?

Near the Load

Far away from the Load

Why?

(2) If you want to put in the shortest distance to lift the load, where should the rotation point be?

Near the Load

Far away from the Load

Why?

Name: _____

What are other types of levers? _____

TODAY'S EXPLORATION QUESTION: (Use the box to draw what you think, label your drawing, and use the lines to explain your thinking.)

KITCHEN TONGS



BAT



STAPLER



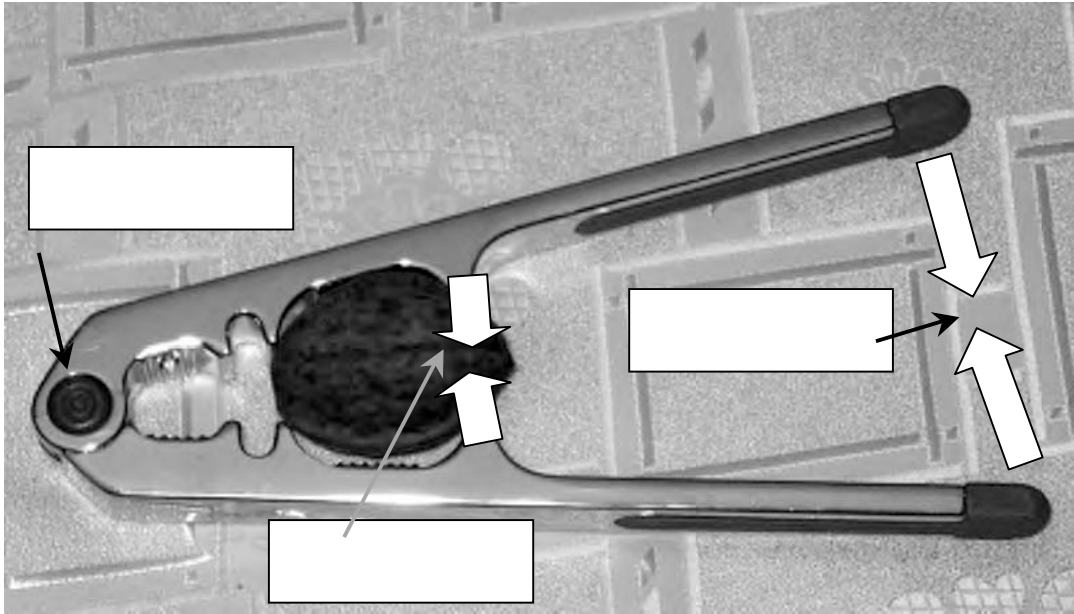
(1) Circle the two objects above you would put in the SAME group. Why would you put them in the same group?

(2) If you had to put all three objects in the SAME group, what are some reasons you could put them in the same group?

Name: _____

What are other types of levers?

(1) PARTS OF A TWO-ARMED LEVER: Look at the nutcracker. Fill in the boxes to label where the load is, where the force is applied, and where the rotation point is.



Word Bank
Load
Force
Rotation Point

(2) When you put force into a nutcracker, the distance of your force depends on the size of the nut.

- When you are cracking a big nut, is the distance of your force shorter or longer than when you are cracking a small nut?

For a big nut, the force's distance is... *shorter* *longer* (Circle one.)

I think the distance is _____ because _____

(3) A nutcracker has TWO forces – your input force and an output force.

- Where do you think the nutcracker's output force is?
- What job does the output force do?

The nutcracker's output force is located _____

The output force does the job of _____

Name:

What are other types of levers?

LEVERS IN EVERDAY LIFE: Think of objects in the classroom and at home that include levers.

(1) What are some one-armed levers that you can think of?
(For example, hammer claws and light switches are one-armed levers.)

(2) What are some two-armed levers that you can think of?
(For example, a clothespin is a two-armed lever.)

Name:

What are other types of levers?

PEOPLE MOVER DESIGN: Now that you know more about simple machines, how have your ideas for your LEGO people mover changed? What are your ideas now about how to move your LEGO person UP and OVER using three simple machines?

(Remember that you may only touch the LEGO person yourself before you turn your machine on.)

Sketch of Idea:

Written explanation of Idea:

Name:

How do wheel-and-axle systems work?

SIMPLE MACHINES – PART 5

TODAY'S EXPLORATION QUESTION: One group of objects shows examples of *rolling wheels*. The other group shows examples of *wheel-and-axle systems*. Which is which? Why?

Group 1:



Steering wheel



Hand mixer or egg beater

Group 2:



Stroller



Skateboard

(1) Which group do you think shows *rolling wheels*?

Group 1

Group 2

(2) Which group do you think shows *wheel-and-axle systems*?

Group 1

Group 2

(3) Why do you think so? On the lines below, write two or three sentences to explain your thinking.

(4) If drawing a picture will help you explain your thinking, use the space below to draw and label a picture that shows what you think.

A large empty rectangular box intended for a student to draw and label a picture illustrating their thinking about rolling wheels or wheel-and-axle systems.

Name:

How do wheel-and-axle systems work?

TODAY'S BIG SCIENCE QUESTION: How can we design wheel-and-axle systems to help us do work?

INVESTIGATION: Build a miniature food mixer to investigate how an object with a *wheel-and-axle system* helps us do work.

MIXER BUILDING INSTRUCTIONS

STEP 1. Find these LEGO pieces and place them in your building area:



(1) 12-stud/long axle



(4) 5-stud/short axles



(2) bushings



(1) 15-hole rounded beam



(2) L-brackets with curves

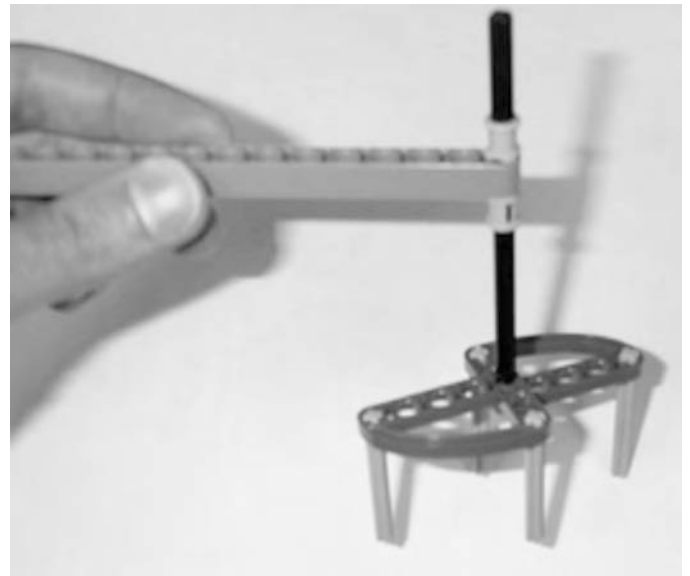
STEP 2. Insert the 12-stud axle through the end of the 15-hole beam. Slide one bushing onto either side of the beam.



STEP 3. Slide the two L-brackets onto the end of the 12-stud axle. They should point in opposite directions.



STEP 4. Insert the four 5-stud axles into the four free axle-shaped holes in the L-brackets.



Name: _____

How do wheel-and-axle systems work?

INVESTIGATION INSTRUCTIONS

STEP 1. Test out four different designs for using the food mixer to mix up the food. Be sure to fill out the two observation columns for each test. The pieces needed are shown here and the completed designs are shown in the chart below.



Handle




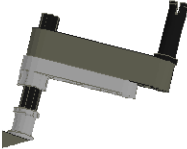
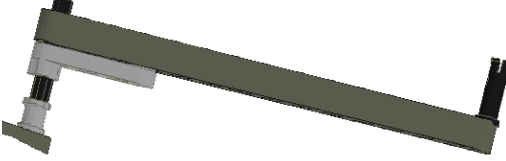
5-hole beam



15-hole beam



Long Connector Peg

	Observations	
Turning Design	How much force does it take to mix the food? (a little, a medium amount, or a lot?)	How far a distance (or how big of a circle) does the handle need to be turned? (shortest, medium, longest)
Axle Only 		
Short Handle (Handle, 5-Hole Beam) 		
Long Handle (Handle, 15-Hole Beam) 	LEGO building note: Slide the axle through the LEGO handle. Attach the beam to the axle and peg on the handle. Insert a long connector peg into the end of the beam.	
Your Own Design		

Name: _____

How do wheel-and-axle systems work?

STEP 2. With your partner, discuss and write answers to the following questions:

(1) Which turning design made it easiest to use the food mixer?

(2) Why do you think this design made your job the easiest?

(3) Which turning design needed the LEAST force to be turned in the mixture?

Axle only

Small handle

Long handle

(4) Which needed to be turned the LEAST distance (smallest circle)?

Axle only

Small handle

Long handle

WHEEL-AND-AXLES IN EVERYDAY LIFE: Think of objects in the classroom and at home.

What are some wheel-and-axle systems that you can think of?

(For example, door knobs and faucet knobs are wheel-and-axle systems.)

Name:

How do wheel-and-axle systems work?

PEOPLE MOVER DESIGN: Now that you know more about simple machines, how have your ideas for your LEGO people mover changed? What are your ideas now about how to move your LEGO person UP and OVER using three simple machines?

(Remember that you may only touch the LEGO person yourself before you turn your machine on.)

Sketch of Idea:

Written explanation of Idea:

Name:

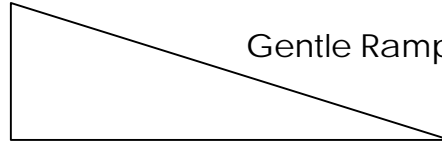
How do inclined planes, screws, and wedges work?

SIMPLE MACHINES– PART 6

TODAY'S EXPLORATION QUESTION 1: Ramps are one of the most common examples of inclined planes.

(A) Circle the ramp that you think would be easier to walk up.

Steep Ramp



Gentle Ramp

(B) Why do you think the ramp you circled would be easier to walk up?

(Use the box to draw what you think, label your drawing, and use the lines to explain your thinking.)

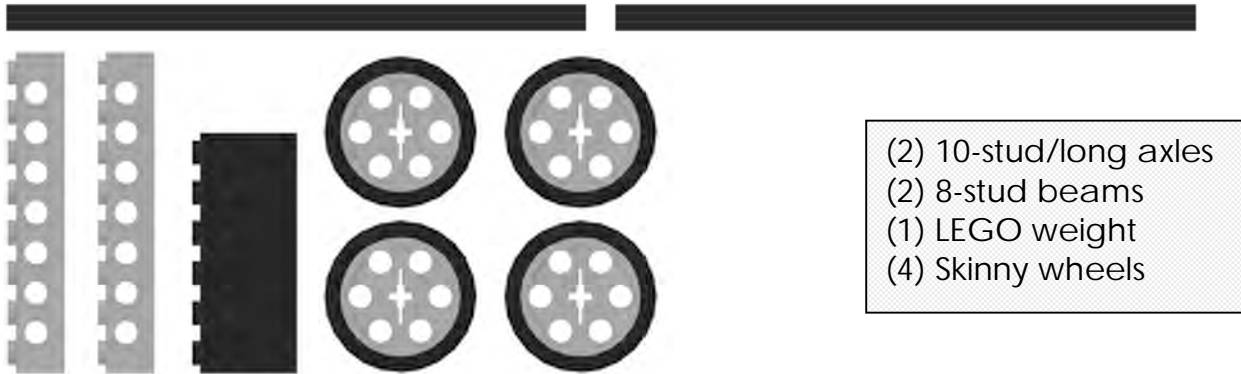
Name: _____

How do inclined planes, screws, and wedges work?

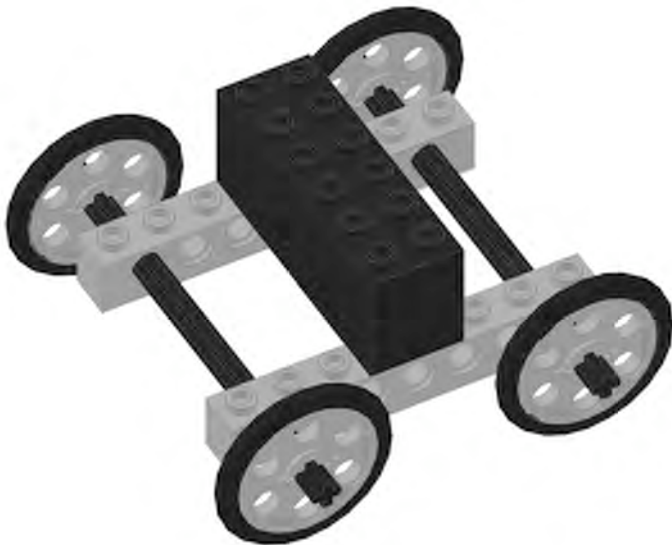
TODAY'S INVESTIGATION: Drag a LEGO cart and weight up a steep and a gentle inclined plane. Decide which inclined plane you would use based on observations.

LEGO CART INSTRUCTIONS:

STEP 1. Take out the following pieces to build the LEGO cart.



STEP 2. Build the LEGO cart shown below. The LEGO weight connects the two beams. The four wheels keep the axles in place and allow the cart to roll.



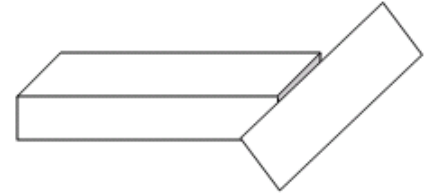
Name: _____

How do inclined planes, screws, and wedges work?

TESTING INSTRUCTIONS: INCLINED PLANES

STEP 1. Hang the load (LEGO weight) from the spring scale. Record the scale reading in the table below (in Newtons). This is how much the load weighs. This is how much force is used to lift the load straight up, with no ramp or inclined plane.

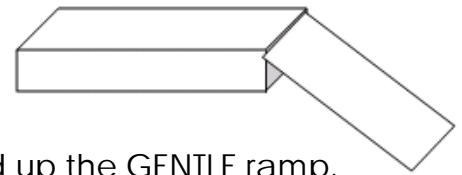
STEP 2. Make a short, STEEP inclined plane by taping the LEGO top to the box:



STEP 3. Hook the spring scale on one of the cart axes.

STEP 4. Use the spring scale to drag the cart and load up the ramp. When the cart is halfway up the ramp, read the spring scale. Record the scale reading in the table below. This is how much force is used to lift the load up the STEEP ramp.

STEP 5. Make a long, GENTLE inclined plane with the LEGO top and box:



STEP 6. Repeat Step 4 to measure the force used to lift the load up the GENTLE ramp.

	Straight Up - No Ramp	Steep Ramp	Gentle Ramp
Lifting Force (Newtons)			

SUMMARY: Think about which inclined plane you would rather use. *Circle the answer to each question below.*

(1) Which inclined plane required the longest length to get to the top of the box?

Gentle Ramp

Steep Ramp

(2) Which inclined plane required the least input force to move the cart to the top of the box?

Gentle Ramp

Steep Ramp

(3) Which inclined plane would you want to use?

Gentle Ramp

Steep Ramp

Why? _____

Name: _____

How do inclined planes, screws, and wedges work?

TODAY'S EXPLORATION 2: Where are the inclined planes in screws? Label the inclined planes in the picture of the screws.



How have you seen screws used?

<i>Object with a screw:</i>	<i>What does this screw help us do:</i>

Name: _____

How do inclined planes, screws, and wedges work?

TODAY'S EXPLORATION 2: Where are the inclined planes in wedges? Label the inclined plane in the pictures of the wedges.



How have you seen wedges used?

<i>Object with a wedge:</i>	<i>What does this wedge help us do:</i>

Name:

How do inclined planes, screws, and wedges work?

PEOPLE MOVER DESIGN: Now that you know more about simple machines, how have your ideas for your LEGO people mover changed? What are your ideas now about how to move your LEGO person UP and OVER using three simple machines?

(Remember that you may only touch the LEGO person yourself before you turn your machine on.)

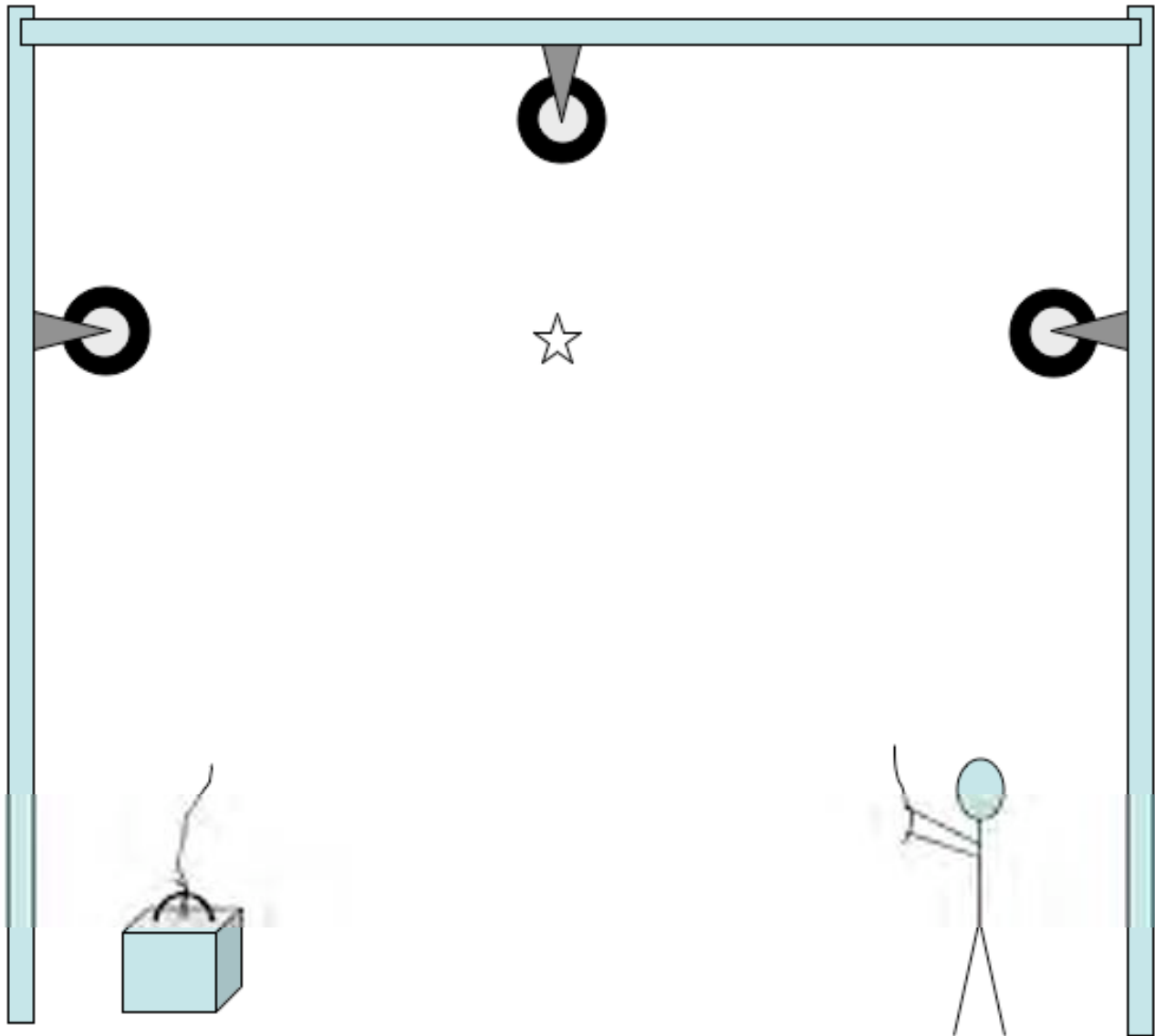
Sketch of Idea:

Written explanation of Idea:

SIMPLE MACHINES – PART 7

TODAY'S EXPLORATION QUESTION: If the person in the picture wants to lift the box up to the star, where should she put the pulley rope?

1) Complete the rope - draw where the rope should go to help her lift the box.

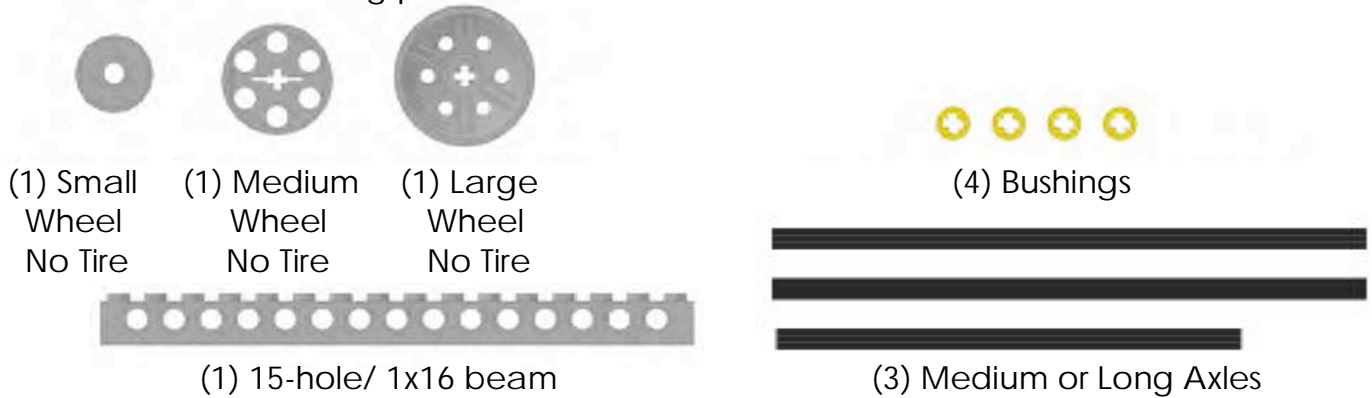


2) Write a sentence to explain why you drew the rope where you did.

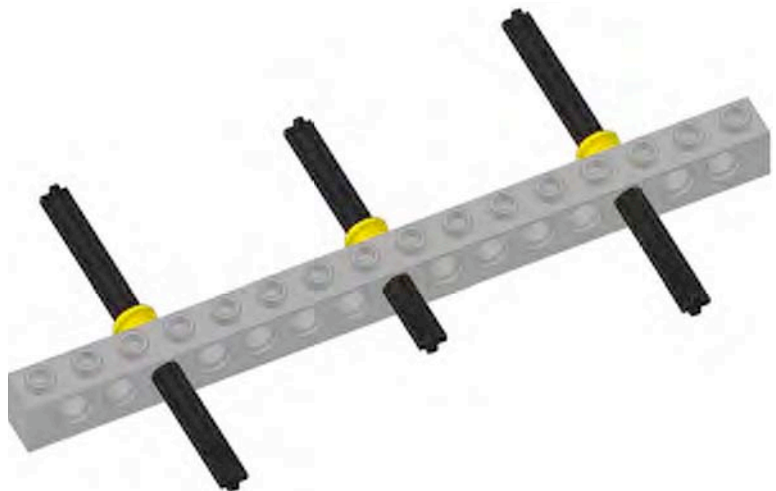
Example Pulley Exercise. Follow along while your teacher demonstrates how to build and test a pulley system.

Build the pulley setup:

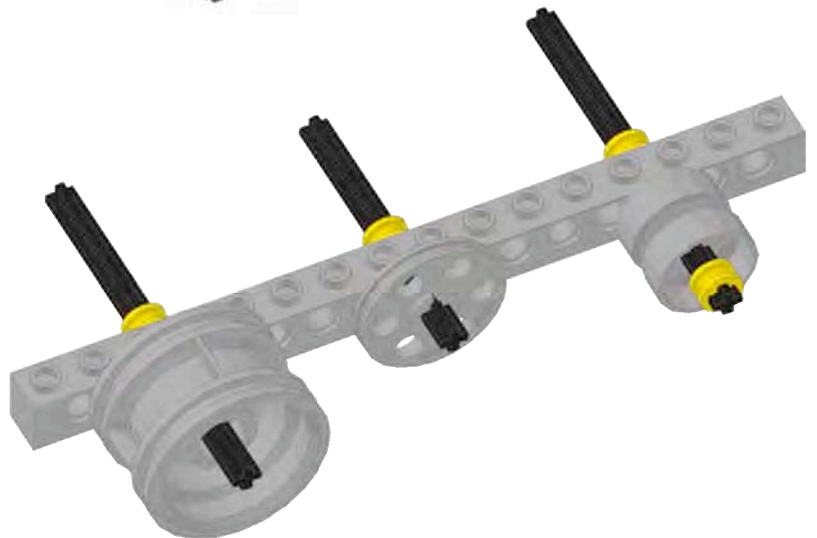
STEP 1. Find the following pieces:



STEP 2. Slide three axles into the beam and slide bushings on one side:



STEP 3. Slide the three wheels onto axles and add one bushing as shown:



Name: _____

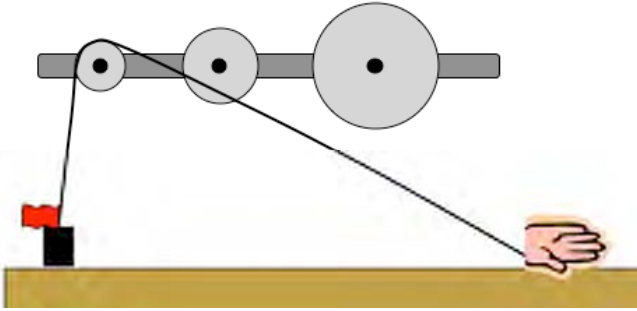
How do pulleys work?

WATCH this:

WRITE this:

Step 1. Hold the beam above the table.

Step 2. Place the weight on the table, pass the string over the smallest pulley wheel, and pull the string until the hook touches the wheel.

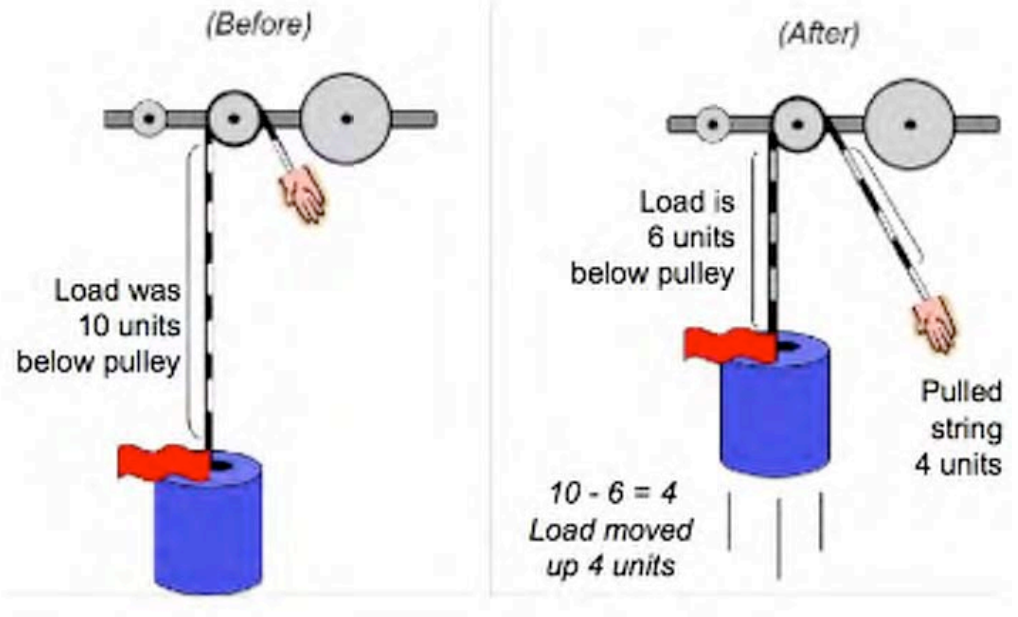


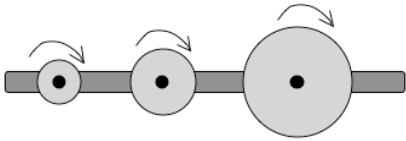
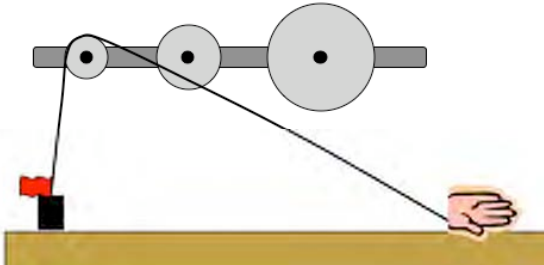
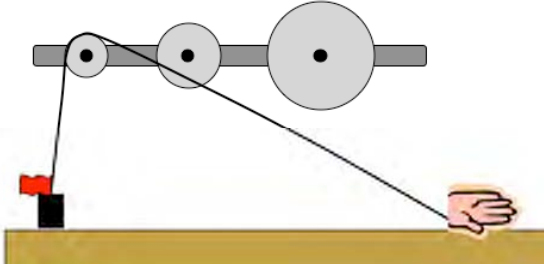
1) The flag moved _____ units.

2) I pulled the string _____ units.

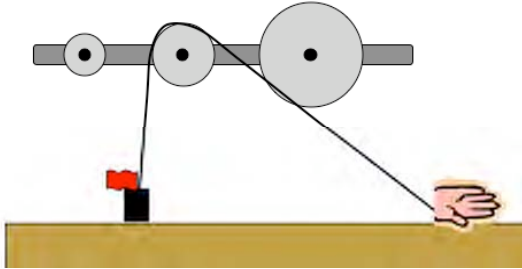
(Use the black and white markings to count the units. Each marking is one unit.)

How to Measure with the Pulley String



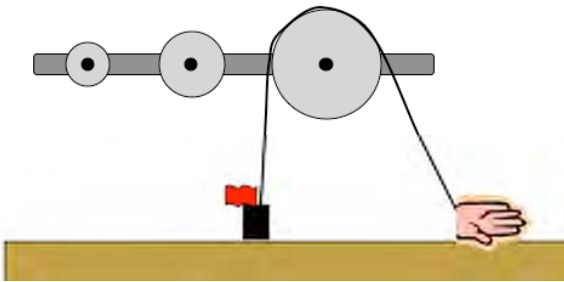
DO this:	WRITE this:
<p>(A) Partners 1 and 2: Look carefully at all three pulley wheels. Give them all a spin and watch how they move.</p> 	<p>1) One thing that I think will be the <i>same</i> about how all three pulley wheels work is ...</p> <p>_____</p> <p>_____</p> <p>2) One thing that I think will be the <i>different</i> about how the different pulley wheels work is ...</p> <p>_____</p> <p>_____</p>
<p>(B) Partner 1: Hold the beam about 12 inches above the table. Partner 2: Place the weight on the desk, pass the string over the <u>smallest</u> pulley wheel, and pull on the end of the string.</p> 	<p>1) When I pull on the string, what happens to the <i>weight</i> is ...</p> <p>_____</p> <p>_____</p> <p>2) When I pull on the string, what happens to the <i>pulley wheel</i> is...</p> <p>_____</p> <p>_____</p>
<p>(C) Partner 1: Hold the beam above the table. Partner 2: Place the weight on the table, pass the string over the <u>smallest</u> pulley wheel, and <u>pull the end of the string along the table</u>.</p> 	<p>1) The hand that is pulling the string is moving ____.</p> <p style="text-align: center;">up down right left</p> <p>2) The weight is moving ____.</p> <p style="text-align: center;">up down right left</p> <p>3) I pulled the string _____ units.</p> <p>4) The weight moved _____ units.</p>

(D)
 Partner 1: Hold the beam above the table.
 Partner 2: Place the weight on the table, pass the string over the medium pulley wheel, and pull the string along the table.



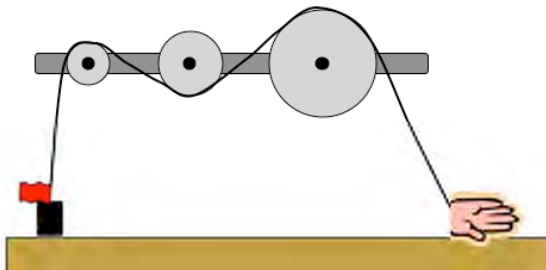
- 1) I pulled the string _____ units.
- 2) The weight moved _____ units.

(E)
 Partner 1: Hold the beam above the table.
 Partner 2: Place the weight on the table, pass the string over the biggest pulley wheel, and pull the string along the table.



- 1) I pulled the string _____ units.
- 2) The weight moved _____ units.



(F)
 Partner 1: Hold the beam above the table.
 Partner 2: Place the weight on the table, pass the string over the smallest pulley wheel, under the medium pulley wheel, and over the biggest pulley wheel. Pull the string along the table.



- 1) The hand that is pulling the string is moving ____.
 up down right left
- 2) The weight is moving ____.
 up down right left
- 3) I pulled the string _____ units.
- 4) The weight moved _____ units.
- 5) The smallest wheel spins _____.
 clockwise counterclockwise
- 6) The medium wheel spins _____.
 clockwise counterclockwise

PULLEY FORCES

At the demonstration station, your teacher will help you explore a fixed pulley and a moveable pulley. Fill in the chart below.

<p>Fixed Single Pulley</p> 	<p>Pulling Distance: _____ cm</p>	<p>Pulling Force: _____ Newtons</p>
<p>Moveable Double Pulley</p> 	<p>Pulling Distance: _____ cm</p>	<p>Pulling Force: _____ Newtons</p>

SUMMARY: Circle the word or phrase that best completes the sentence.

(1) The force for lifting a load with a moveable double pulley is about _____ the force for lifting a load with a fixed single pulley.

double

the same

half

(2) When I pull the string in a fixed single pulley system, the load moves _____.

the same distance my hand moves

half the distance my hand moves

(3) When I pull the string in a moveable double pulley system, the load moves _____.

the same distance my hand moves

half the distance my hand moves

Name:

How do pulleys work?

PEOPLE MOVER DESIGN: Now that you know more about simple machines, how have your ideas for your LEGO people mover changed? What are your ideas now about how to move your LEGO person UP and OVER using three simple machines?

(Remember that you may only touch the LEGO person yourself before you turn your machine on.)

Sketch of Idea:

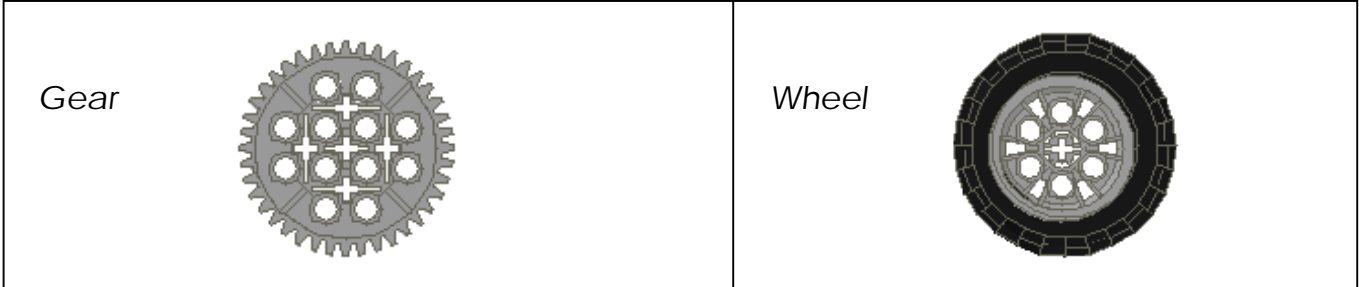
Written explanation of Idea:

Name:

How do gears change circular motion?

SIMPLE MACHINES- PART 8

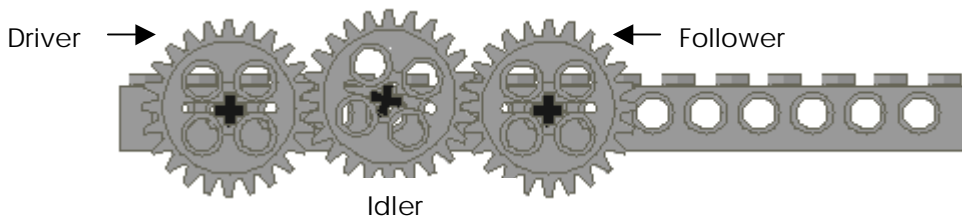
TODAY'S EXPLORATION QUESTION: How can you tell the difference between a gear and a wheel?



One way a gear and a wheel are the same is:

One way a gear and a wheel are different is:

Example Gear Train:

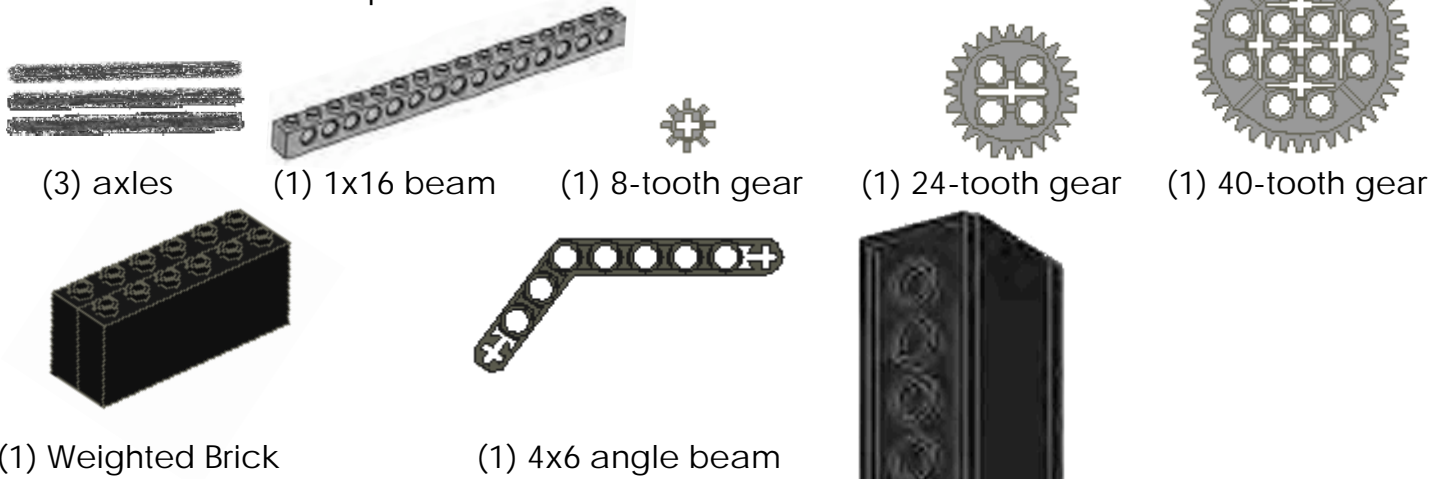


Name: _____

How do gears change circular motion?

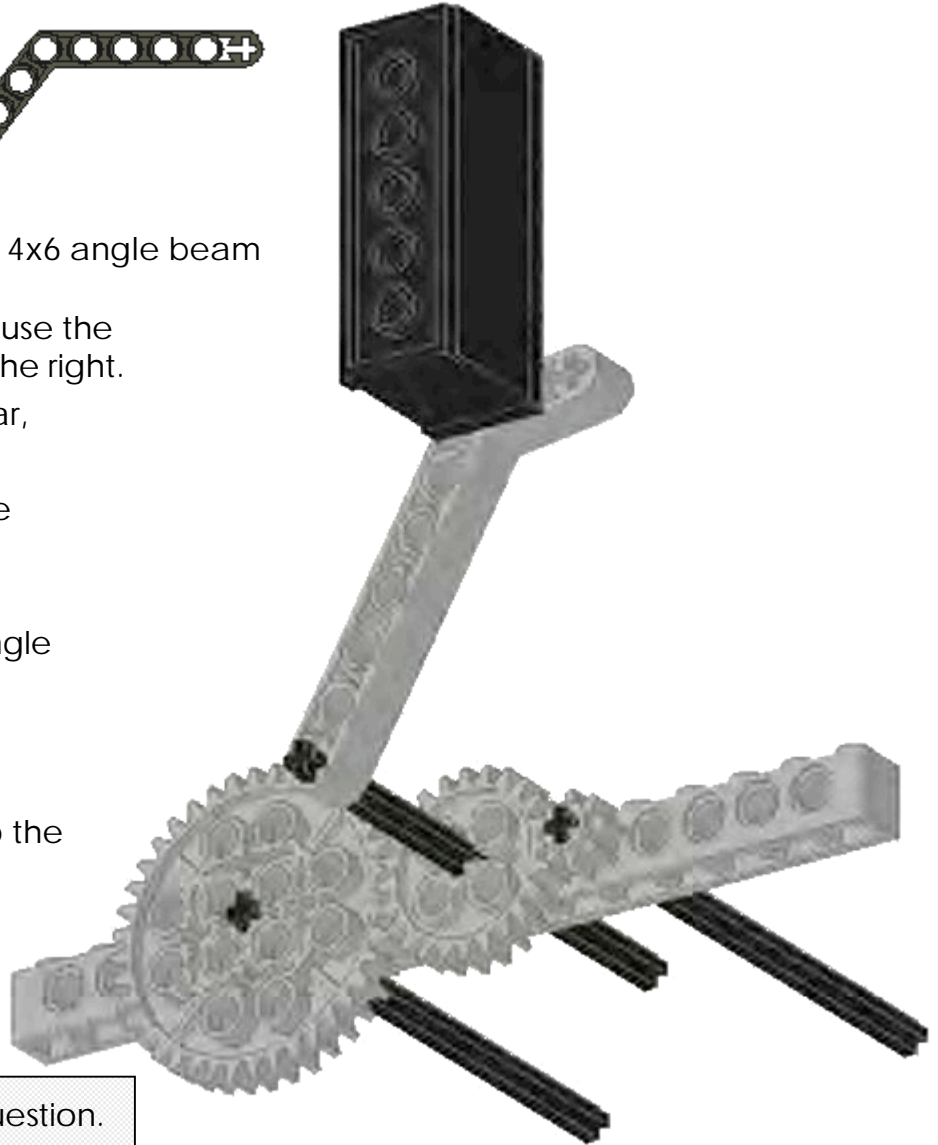
GEARS EXPLORATION 1: Investigate how hard it is to turn gears (the force) and how far you have to turn gears to move something (the distance).

STEP 1. Find these LEGO pieces:



STEP 2. Follow the instructions and use the picture to build the gear train on the right.

- 1) Connect one axle to each gear, making three gear 'lollipops'
- 2) Slide the gear lollipops onto the beam in the order shown
- 3) Make the axle on the medium gear stick out further so the angle beam can connect to it
- 4) Attach the angle beam to the medium gear axle
- 5) Connect the weighted brick to the two holes in the slanted beam



STEP 3. Circle the answer to the question.

(1) What is the advantage of using the small gear to turn the weight (the load)?

Less Force to Turn

Less Distance (Fewer Turns) to Turn

(2) What is the advantage of using the large gear to turn the weight (the load)?

Less Force to Turn

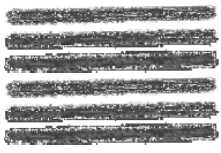
Less Distance (Fewer Turns) to Turn

Name: _____

How do gears change circular motion?

GEARS EXPLORATION 2: Investigate the direction and speed of different kinds of gear trains.

STEP 1. Find these LEGO pieces:



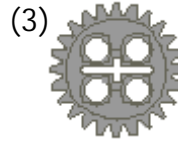
(6) axles



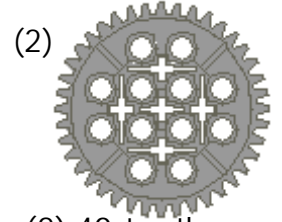
(1) 1x16 beam



(1) 8-tooth gear

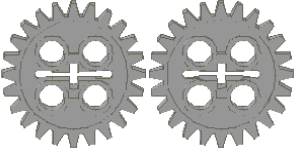
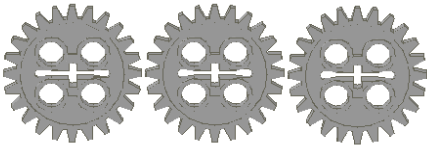
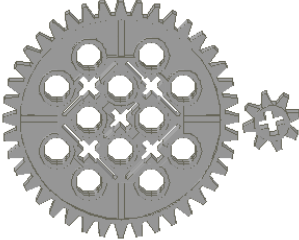
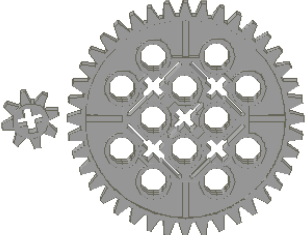
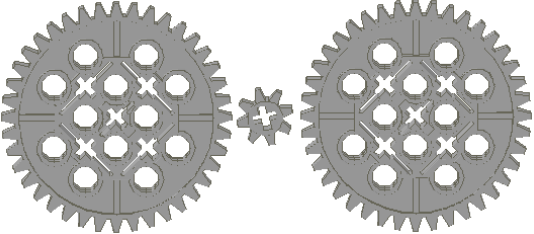
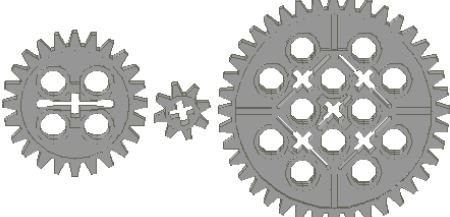


(3) 24-tooth gear



(2) 40-tooth gear

STEP 2. Build these gear trains and answer the question about them.

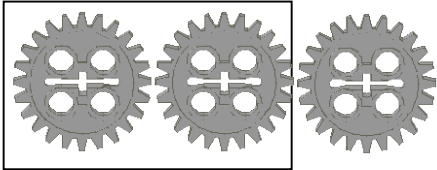
Gear Train	Circle the answer to complete the sentence.
	When the first gear turns right, the second gear turns: <i>left</i> <i>right</i> The gears turn at _____ speeds. <i>the same</i> <i>different</i>
	When the first gear turns right, the second gear turns: <i>left</i> <i>right</i> the third gear turns: <i>left</i> <i>right</i>
	The big gear turns <i>faster</i> <i>slower</i> than the small gear.
	The small gear turns <i>faster</i> <i>slower</i> than the big gear.
	The big gears turn at <i>the same</i> <i>different</i> speeds.
	The fastest gear is the <i>smallest</i> <i>medium</i> <i>largest</i> The slowest gear is the: <i>smallest</i> <i>medium</i> <i>largest</i>

Name: _____

How do gears change circular motion?

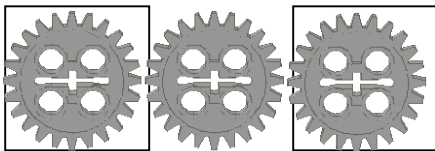
SUMMARY: Circle the answer to each question.

(1) Gears that are *next to each other* spin in the _____ direction.



same opposite

(2) Gears with *another gear in between them* spin in the _____ direction.



same opposite

(3) When big and small gears are next to each other, the *big* gear spins _____
than the *small* gear.

slower faster

(4) When big and small gears are next to each other, the *small* gear spins _____
than the *big* gear.

slower faster

Name: _____

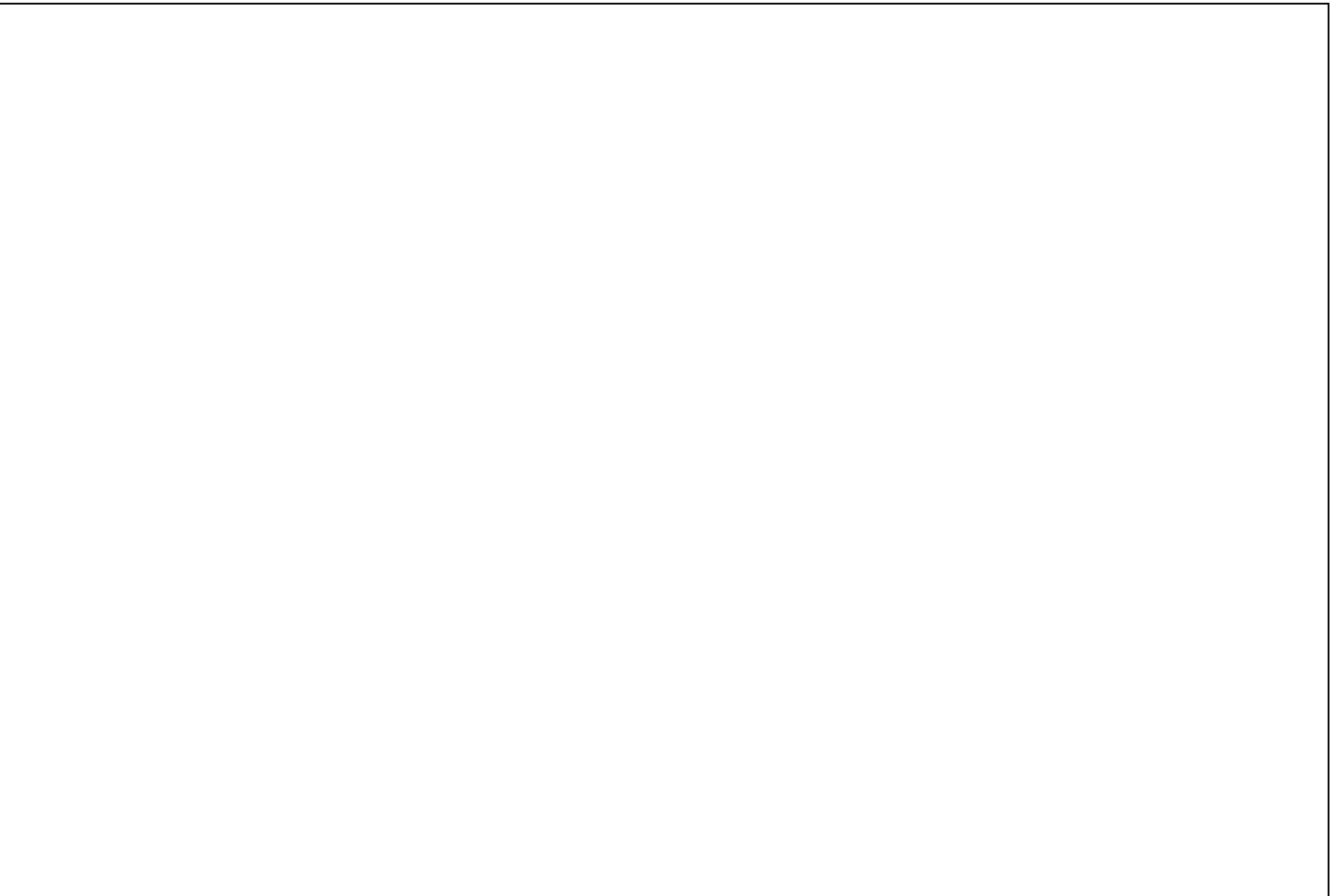
How do gears change circular motion?

GEAR TRAIN DESIGN CHALLENGE: Design a gear train that will run an optical illusion machine. You will add an optical illusion disk to the *follower* gear in your train.

Your gear train must:

- Have enough gears to fill up *an entire 1x16 beam*
- Make the follower gear spin *much faster* than the driver gear.

Draw and label your optical illusion gear train so that another student could build it.



Extra Challenges:

- (1) Add even more gears to your train but make sure it keeps working.
- (2) Change your gear train so that the follower gear spins even faster.

Hint: You could put TWO gears on the same axle to make the gear train spin even faster!



Name:

How do gears change circular motion?

PEOPLE MOVER DESIGN: Now that you know more about simple machines, how have your ideas for your LEGO people mover changed? What are your ideas now about how to move your LEGO person UP and OVER using three simple machines?

(Remember that you may only touch the LEGO person yourself before you turn your machine on.)

Sketch of Idea:

Written explanation of Idea:

Name:

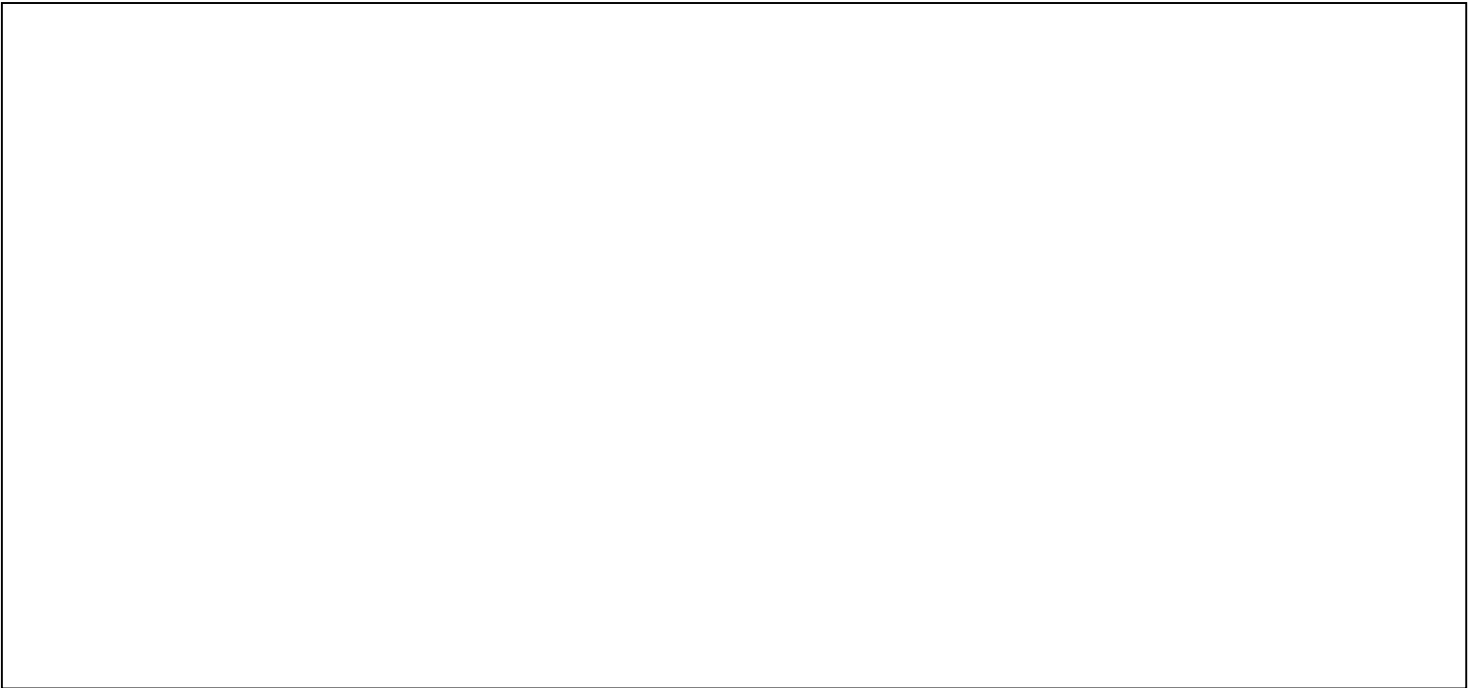
How can we find simple machines in complex machines?

SIMPLE MACHINES– PART 9

TODAY'S EXPLORATION QUESTION: Now you have learned about seven simple machines. There are also complex machines.

What is the difference between a simple machine and a complex machine?

In the space below, write and draw your answer to this question. If you don't know, take a guess.



Name: _____

How can we find simple machines in complex machines?

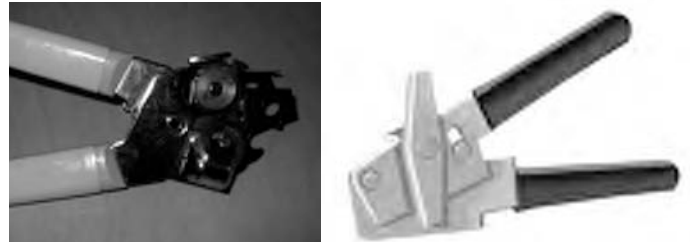
FINDING SIMPLE MACHINES: Here are 4 complex machines. List the simple machines in each complex machine. Remember you have learned about levers, wheels and axles, inclined planes, screws, wedges, gears, and pulleys. Even though there are FOUR lines under each complex machine, there does NOT need to be four simple machines in each one!

(1) Scissors



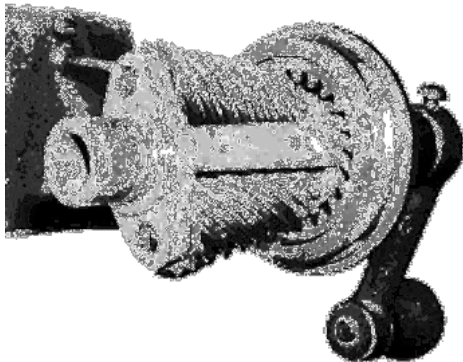
The simple machines in scissors are:

(2) Can Opener



The simple machines in a can opener are:

(3) Pencil Sharpener



The simple machines in a pencil sharpener are:

(4) Crane

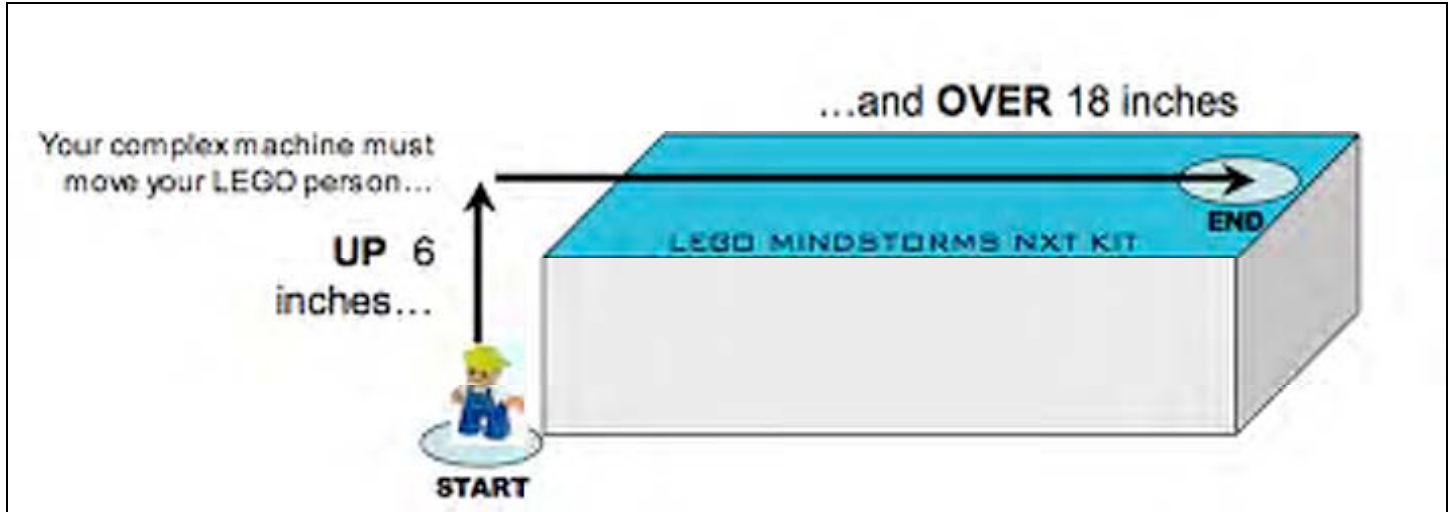


The simple machines in a crane are:

Name: _____

How can we find simple machines in complex machines?

FINAL DESIGN CHALLENGE: Make a **COMPLEX** machine that can move a LEGO person **UP** 6 inches and **OVER** 18 inches (to the top of an NXT kit, and from one end of the kit to the other). Your complex machine must use at least three simple machines. *Once you turn your machine on, you may not touch your LEGO person until the end of the UP-and-OVER move.*



STEP 1. Brainstorm one idea for a complex machine that will move your LEGO person **UP** and **OVER** using three simple machines. *Remember that you may only touch the LEGO person yourself before you turn your machine on.*

STEP 2. Write and sketch about your idea in the boxes below.

Sketch of Idea #1:

Written explanation of Idea #1:

Simple machines used in Idea #1 (at least 3)

- 1) _____
- 2) _____
- 3) _____

Name: _____

How can we find simple machines in complex machines?

STEP 3. Talk with your partner. Working together, brainstorm a way to COMBINE your ideas for a complex machine that will move your LEGO person UP and OVER. Remember that you may only touch the LEGO person yourself before you turn your machine on.

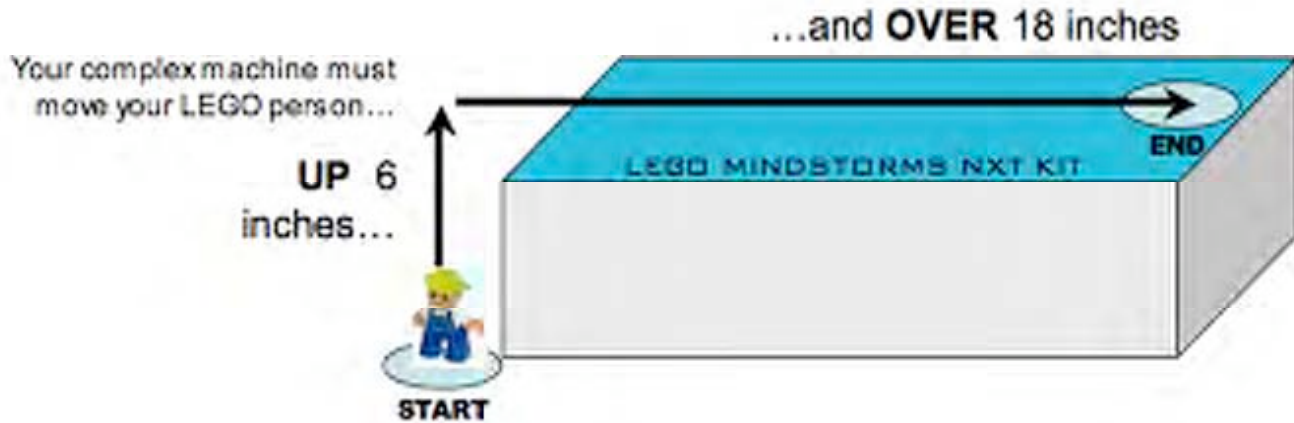
<p>Sketch of Idea #2:</p>	<p>Written explanation of Idea #2:</p> <hr/> <hr/> <hr/> <hr/> <hr/> <hr/> <p>Simple machines used in Idea #2 (at least 3)</p> <p>1) _____</p> <p>2) _____</p> <p>3) _____</p>
---------------------------	--

STEP 4. Show and explain your ideas to your teacher. Your partner needs to be able to show and explain the combined idea, too. Only if you can fully explain your idea will you be able to get your kit and start building!

Name: _____ What simple machines can be used to create a model people mover?

SIMPLE MACHINES – PART 10

FINAL DESIGN CHALLENGE: Make a **COMPLEX** machine that can move a LEGO person **UP 6 inches** and **OVER 18 inches** (to the top of an NXT kit, and from one end of the kit to the other). Your complex machine must use at least three simple machines. *Once you turn your machine on, you may not touch your LEGO person until the end of the UP-and-OVER move.*



STEP 1. Review the complex machine plans that you created with your partner.

STEP 2. Work together to build your LEGO-person-moving complex machine.

STEP 3. Test your machine. If it doesn't work, re-design, re-build, and re-test until it does.

STEP 4. When your machine works the way you want it to, fill out the RUBRIC on the next page and use the space on the following page to draw and label your finished machine.

Names: _____, _____, _____

Rubric for People Mover

	Modelers: Circle your self-evaluation below.	Jobs of your simple machines: (Reminder: the seven simple machines are levers, wheels-and-axles, inclined planes, screws, wedges, gears, and pulleys)
Does our model use three simple machines ?	Yes (1 pt) No (0 pt)	Name your first simple machine: _____ (1) Where is its input force? _____ _____
Once the LEGO person is attached to the machine we do not have to touch it again.	Yes (1 pt) No (0 pt)	(2) Where is its output force? _____ _____
Our complex machine only needs to be touched once for it to run.	Yes (1 pt) No (0 pt)	----- Name your second simple machine: _____ (1) Where is its input force? _____ _____
Our model can move the LEGO man up and across the NXT box.	Yes (1 pt) No (0 pt)	(2) Where is its output force? _____ _____
Our model can move the LEGO man and weight baggage up and across the NXT box.	Yes (1 pt) No (0 pt)	----- Name your third simple machine: _____ (1) Where is its input force? _____ _____
<i>Challenge 1:</i> Our model can move the LEGO man up and across the NXT box in less than 10 seconds .	Yes (1 pt) No (0 pt)	(2) Where is its output force? _____ _____
<i>Challenge 2:</i> Our model can move the LEGO man and weight up and across the NXT box in less than 10 seconds .	Yes (1 pt) No (0 pt)	_____ _____

Name:

What simple machines can be used to create a model people mover?

Engineering diagram of our person-moving machine:

The simple machines within our complex machine are:

STEP 5. Label the LEGO parts and the simple machines in your diagram.

Name:

How do simple machines help us?

SIMPLE MACHINES – PART 11

STEP 1. Set up your complex machine prototype.

STEP 2. When it is your team's turn to present, another pair of students will need to see your machine in action. Show them how your machine works and answer their questions.

STEP 3. When it is your team's turn to review, watch how the other pair's machine works. Ask questions about the machine so that you understand it very well. Write what you learn in the spaces below.

Your People-Mover

What simple machines does your people-mover use to move the LEGO person UP?

What simple machines does your people-mover use to move the LEGO person ACROSS?

Another Team's People-Mover

What simple machines does their people-mover use to move the LEGO person UP?

What simple machines does their people-mover use to move the LEGO person ACROSS?

Name:

How do simple machines help us?

Group	Simple machines that help move the LEGO person UP:	Simple machines that help move the LEGO person ACROSS:
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

What are the simple machines?

- Lever
- Wheel-and-Axle
- Gear
- Pulley
- Inclined Plane
- Screw
- Wedge

Simple machines that help to split or cut:	Simple machines that help to change direction:	Simple machines that help to change speed:	Simple machines that help to change how much effort we put in:

Section 3: Supplemental Teacher Resources

THE PACE CENTER



Tufts | Center for Engineering
UNIVERSITY | Education and Outreach

LEGO® engineering

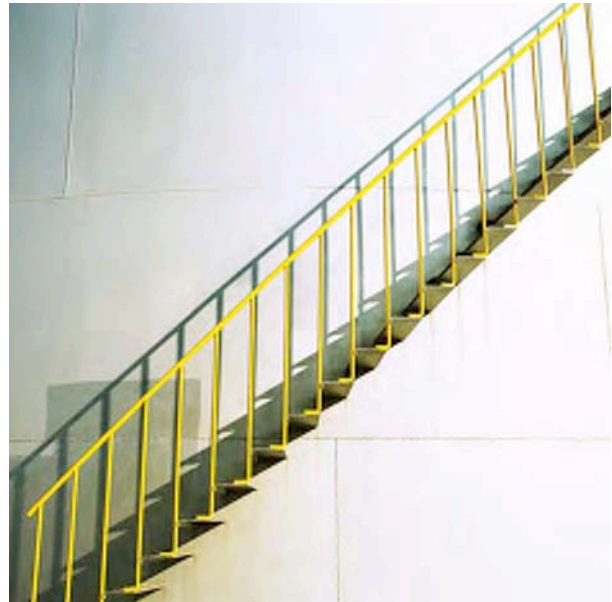
Levers



Wheels-and- Axles



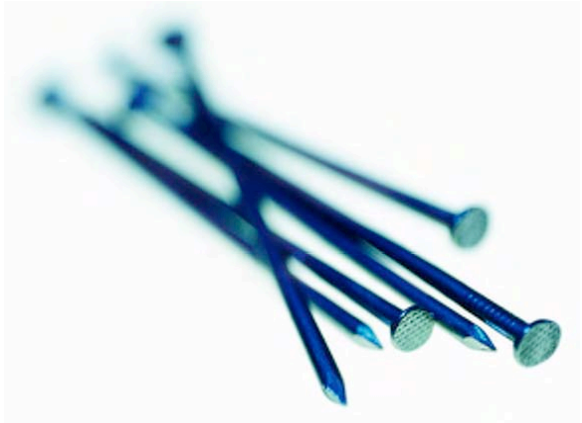
Inclined Plane



Screw



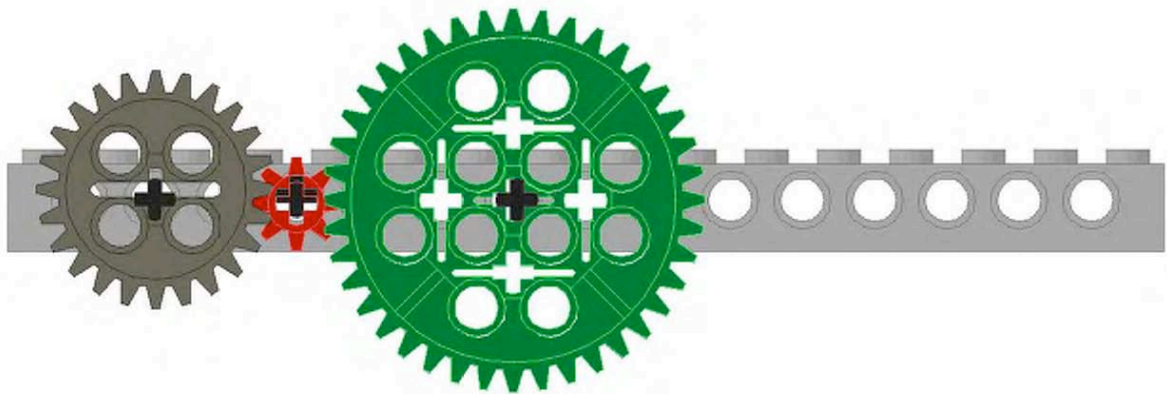
Wedge





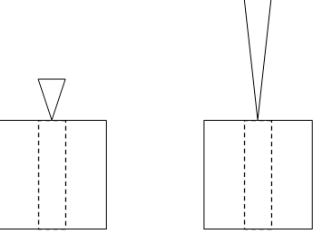
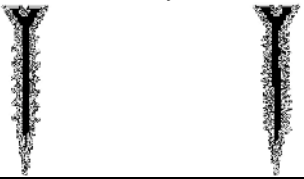

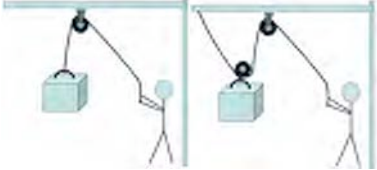
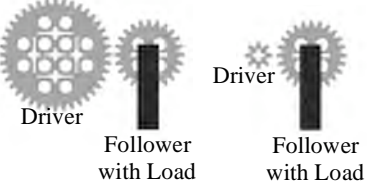
Pulley



Gears



How Can We Design Simple Machines To Be Most Helpful For Doing Work?

Simple Machine	Design "Rules of Thumb"	
	How to Put in Less Force	Tradeoff for Putting in Less Force
Lever	Move Fulcrum Closer to Load 	Have to Push Lever for a Longer Distance AND Lever May be High in the Air When Push on It
Wheel-and-Axle System	Bigger/Longer Wheel or Handle 	Larger Rotation Distance/Circle
Wedge	Longer/Thinner/Steeper Wedge 	Have to Push Wedge for Longer Distance to Make Same-Sized Cut
Screw	Inclined Plane Wrapped Tightly around Cylinder 	Have to Spin more Times (more Distance) to Get the Screw in
Inclined Plane	Use Gentler Inclined Plane 	Inclined Plane will be Longer
Pulley	Use Moveable Pulley 	Moveable Pulley Requires the Rope be Pulled for TWICE the Distance to Move Something to the Same Height
Gear	Use Smaller Gear as Driver 	Have to Turn the Small Gear More time to Get the Follower to Go the Same Distance/Spin in a Full Circle

Simple Machines Unit Glossary

Lesson 1

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Trade-off – Plus and minus, positive and negative, the trading of one thing for another, usually perceived to be advantageous or complimentary.

Optimal – The best or most favorable.

Consultant – A person who gives professional advice.

Pitch – A brief presentation/summary of an idea used to convince others that one's solution or idea is best or optimal.

Lesson 2

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Machine - A man-made device, usually driven by a motor or engine, with a system of interrelated parts that work together to perform a task.

Simple Machine - Anything that has few parts and makes it easier to do a task.

Complex Machine - A combination of two or more simple machines.

Lever - A stiff bar that rotates around a fixed point and makes it easier to lift a load or apply a force.

Pulley - A wheel with grooved edges for ropes that is used to change the direction of a pull and make it easier to lift a load.

Wheel - A disk or circular frame that revolves on an axle.

Axle - A pin, pole, or bar on or with which a wheel revolves.

Wheel-and-Axle - Two differently sized wheels attached to the same axis that are used to make circular motion easier.

Screw - Inclined planes wrapped around a cylinder that are used to raise and lower objects and hold objects together.

Wedge - Two inclined planes joined back to back to form a sharp edge that are used to change the direction of a force and often result in the splitting of objects.

Inclined Plane - A surface slanted upwards that lowers the effort needed to lift a load.

Gear - A wheel with teeth around the edge that is used to turn other gears and change the direction, speed, and force of circular motion.

Lesson 3

Lever - A straight bar that rotates around a fixed point and makes it easier to lift a load or apply a force.

Rigid - Not flexible, stiff.

Pry - To move, lift, or open with something that acts as a lever.

Rotate - To turn or cause to turn around an axis or a center.

Rotation Point - The axis or center that a wheel or disk spins.

Work - The use of force to move an object a certain distance.

Force - A push or a pull.

Distance - The space between two points, lines, surfaces, or objects.

Load - The object being lifted or moved by a machine.

Lever Arm - Part of lever that goes around the rotation point and has a force applied to it.

Horizontal - On the same level as the horizon or line of the floor.

Trade-off - Plus and minus, positive and negative, the trading of one thing for another, usually perceived to be advantageous or complimentary.

Lesson 4

Lever - A straight bar that rotates around a fixed point and makes it easier to lift a load or apply a force.

Rotate - To turn or cause to turn around an axis or a center.

Rotation Point - The axis or center that a wheel or disk spins around.

Work - The use of force to move an object a certain distance.

Squeeze - To press something firmly together from both sides.

Force - A push or a pull.

Distance - The space between two points, lines, surfaces, or objects.

Load - The object being lifted or moved by a machine.

Lever Arm - Part of lever that goes around the rotation point and has a force applied to it.

Trade-off - Plus and minus, positive and negative, the trading of one thing for another, usually perceived to be advantageous or complimentary.

Lesson 5

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Wheel - A disk or circular frame that revolves on an axle.

Axle - A pin, pole, or bar on or with which a wheel revolves.

Wheel-and-Axle - Two differently sized wheels attached to the same axis that are used to make circular motion easier.

Force - A push or a pull.

Lesson 6

Steep - Having a very sharp slope or incline.

Gentle - Having a gradual or mild slope or incline.

Force - A push or a pull.

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Inclined Plane - A surfaces slanted upward that lowers the effort needed to lift a load.

Screw - Inclined planes wrapped around a cylinder that are used to raise and lower objects and hold objects together.

Wedge - Two inclined planes joined back to back to form a sharp edge that are used to change the direction of a force and often result in the splitting of objects.

Spring Scale - A device for weighing that uses a hanging spring to measure the weight of an object.

Lesson 7

Pulley - A wheel with grooved edges for ropes that is used to change the direction of a pull and make it easier to lift a load.

Wheel - A disk or circular frame that revolves on an axle.

Fixed Pulley - Pulley that always stays in one place

Moveable Pulley - Pulley that can move along the rope it connects to.

Force - A push or a pull.

Load - The object being lifted or moved by a machine.

Spring Scale - A device for weighing that uses a hanging spring to measure the weight of an object.

Lesson 8

Gear - A wheel with teeth around the edge that is used to turn other gears and change the direction, speed, and force of circular motion.

Teeth - The projections on the rim of a gear that fit between the projections on another gear.

Gear Train - A set of gears that work together to transmit a force.

Driver Gear - The gear in a gear train that provides the power to the other gears (usually gets power from a motor).

Idler - A gear or wheel that transmits motion between two other gears without change of direction or speed.

Follower Gear - The gear that moves last/outputs power in a gear train.

Motion - The process of changing place, movement.

Circular Motion - Movement in a round or circle pattern.

Direction - The way in which one may face or travel.

Force - A push or a pull.

Lesson 9

Engineering - The process of creating solutions to human problems through creativity and the application of math and science knowledge.

Simple Machine - Anything that has few parts and makes it easier to do a task.

Complex Machine - A combination of two or more simple machines.

Lesson 10 & Lesson 11

Same as Lesson 9
