The NASA SCI Files™
The Case of the
Powerful Pulleys

Segment 4

The tree house detectives have finally found the solution to lifting Jacob safely into the tree house…pulleys. However, they still don't have an adequate number of pulleys to reduce the force sufficiently to make lifting Jacob easy for them, and they can't figure out what to do with all that rope! While on vacation, Anthony visits Legoland® to learn about gears and decides that gears are the answer. Now the detectives think they have not only solved the problem of force, but that they have even solved the problem of too much rope. As Bianca wraps up her career day presentation, the tree house detectives finish building their lift apparatus. Finally, they lift Jacob successfully into the tree house! However, there is just one small problem….

Objectives

The students will

- determine how the number of teeth on a gear reduces the amount of force.
- compare the length of the handle of a winch to the spool to determine the decreased amount of force.
- discover what materials are used to overcome friction.
- create a way to get Jacob down from the tree house.
- create a compound machine to complete a task.

Vocabulary

belay - to make (as a rope) tight by turns around a cleat or pin

Imagineer – a person who works at Legoland®, CA designing and creating Lego® models

ratchet - a mechanical device that consists of a bar or wheel having slanted teeth into which a pawl (hinged or pivoted catch) drops so as to allow motion in one direction only

Video Component

Implementation Stratey

The NASA SCI Files™ is designed to enhance and enrich the existing curriculum. Two to three days of class time are suggested for each segment to fully use video, resources, activities, and web site.

Before Viewing

1. Prior to viewing Segment 4 of *The Case of the Powerful Pulleys*, discuss the previous segment to review the problem and what the tree house detectives have learned thus far. Download a copy of the Problem Board from the NASA SCI Files™ web site and have students use it to sort the information learned so far.
2. Review the list of questions and issues that the students created prior to viewing Segment 3 and determine which, if any, were answered in the video or in the students' own research.
3. Revise and correct any misconceptions that may have been dispelled during Segment 3. Use tools located on the Web, as was previously mentioned in Segment 3.
4. Focus Questions-Print the questions from the web site ahead of time for students to copy into their science journals. Encourage students to take notes during the program to answer the questions. An icon will appear when the answer is near.

View Segment 4 of the Video

For optimal educational benefit, view *The Case of the Powerful Pulleys* in 15-minute segments and not in its entirety. If you are viewing a taped copy of the program, you may want to stop the video when the Focus Question icon appears to allow students time to answer the question.

After Viewing

1. At the end of Segment 4, lead students in a discussion of the focus questions for Segment 4.
2. Have students discuss and reflect upon the process that the tree house detectives used to design a safe lifting apparatus for Jacob. The following instructional tools located in the educator's area of the web site may aid in the discussion: Experimental Inquiry Process Flowchart and/or Scientific Method Flowchart.
3. Choose activities from the educator guide and web site to reinforce concepts discussed in the segment. Pinpoint areas in your curriculum that may need to be reinforced and use activities to aid student understanding in those areas.
4. Wrap up the featured online Problem-Based Learning investigation. Evaluate the students' or team's final product generated to represent the online PBL investigation. Sample evaluation tools can be found in the educator's area of the web site under the main menu topic "Tools."

2001 – 2002 NASA "Why?" Files Programs

5. Have students write in their journals what they have learned about simple machines, force, friction, and/or the problem-solving process and share their entry with a partner or the class.

Resources

Books

Baker, Wendy and Andrew Haslam: *Make It Work! Machines.* Thomson Learning, 1994, ISBN: 1568472560.

Burton, Virginia Lee: *Mike Mulligan and His Steam Shovel.* Houghton Mifflin Company, 1977, ISBN: 0395259398.

Gardner, Robert: *Science and Sports. F. Watts*, 1988, ISBN: 0531105938.

Morgan, Sally and Adrian: *Designs in Science: Using Energy*. Facts on File, Inc., 1993, ISBN: 0816029849.

Careers

Imagineer
rock climber
electrical engineer
structural engineer

Web Sites

Lego® Just Imagine
Explore the world of Legos® and Legoland®. This web site has interactive games, adventures, and even a Kids' club.
http://www.lego.com/

Those Crazy Lego® Screws!
Read an in-depth explanation of the screw and take a look at three examples made from Legos®.
http://weirdrichard.com/screw.htm

Inventor's Toolbox: The Elements of Machines.
See real-life pictures of simple machines with descriptions and examples.
http://www.mos.org/sln/Leonardo/InventorsToolbox.html

Activities and Worksheets

Get Your Gears Here

Purpose

To understand how gears work

Materials

corrugated cardboard
jar lids of different sizes
push pins
foam board (15 cm X 30 cm)
2-3 cm dowel pegs
glue
metric measuring tape
small nail
hammer
marker
science journal

Procedure

1. Choose several different sized jar lids and measure the circumference of each. Record in your science journal.
2. Cut strips of corrugated cardboard 1.5 cm wide by the length (determined by the circumference) for each lid.
3. Count the number of "teeth" (ridges in the cardboard) for each strip. If there are an odd number of teeth, cut one tooth off to make it an even number.
4. Carefully stretch the cardboard so that the teeth are facing outward and are evenly spaced around the edge of the lid. Glue into place. See diagram 1.
5. Glue a small wooden dowel to the edge of each gear. See diagram 2.
6. Once the glue is dry, use a compass to find the center of the lid.
7. Use a small nail and hammer to make a hole in the center of the lid.
8. Using the push pins, pin the gears to the foam board so that the teeth of each gear mesh with the teeth of another gear. The gears should spin freely and be arranged in order from smallest to largest.
9. Use a marker to mark a starting point for each gear. Line the dowel up with the marker. See diagram 3.
10. Experiment with turning the gears and observe what happens.
11. Record your observations in your science journal and answer the conclusion questions.

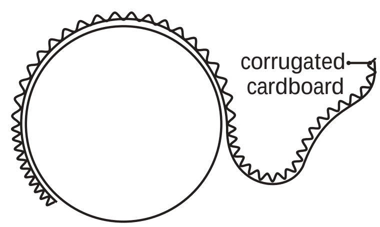


Diagram 1

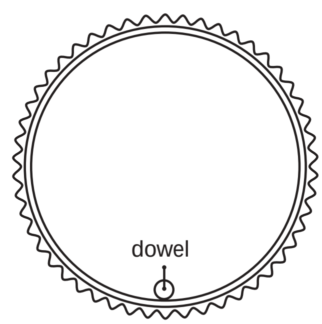


Diagram 2

Conclusion

1. When you turned the largest gear, what happened to the two smaller gears?
2. Which way did they turn?
3. Which gear did a complete turn first?
4. When you turned the smallest gear, did the largest gear turn more quickly or more slowly?
5. Turn the smallest gear one complete turn and count the number of teeth that pass the starting point for the middle gear and for the largest gear. What can you conclude from this comparison?

Extensions

1. Find objects such as a hand-powered eggbeater, bicycle, clock, and so on that use gears. Observe how they work.
2. Count the teeth in both sprocket wheels of a bike. Predict how many turns the rear wheel will make for every turn of the pedals. What would happen if a smaller sprocket were used on the rear wheel?
3. Tie a ribbon around a spoke of a bike's rear wheel. Predict how many turns the wheel will make as the pedals go around once. Turn the bike upside down and turn the pedal once.

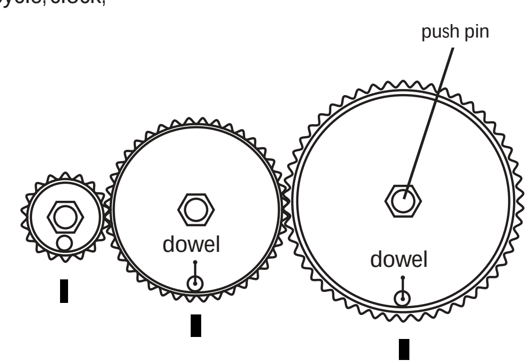


Diagram 3

Crank It Up!

Materials

pencil sharpener attached to wall
3-m string
small weight
scale
metric ruler
20-cm dowel
duct tape
science journal

Purpose

To use a crank handle to lift an object and determine the force

Procedure

1. Use the scale to weigh the load and record weight in science journal.
2. Remove the cover of the pencil sharpener.
3. Measure to determine the radius of the pencil sharpener barrel and record it in science journal.
4. Measure the length of the crank arm and record.
5. To determine the ratio between the crank arm and the barrel, divide the length of the crank arm by the radius of the barrel. Example: 10/2 = 5/1 or 10 cm ÷ 2 cm = 5. The ratio is 5 to 1 (5:1). The ratio means that for every unit of force you apply, it is multiplied five times with the crank arm. Calculate your ratio and record.
6. Securely tie one end of the string to the barrel.
7. Tie the other end of the string to the weight (load).
8. Turn the handle of the pencil sharpener (crank) to lift the load to the top.
9. Lower the weight to the floor.
10. To calculate how much force you used to lift the load, divide the weight by the amount your force was multiplied (ratio). Calculate and record.
11. Using tape, secure the dowel to the crank arm to extend the arm.
12. Calculate the ratio and find the amount of force needed to lift the load with the longer crank arm.
13. Repeat steps 8-9 and record your observations.
14. Going just by how it felt, compare the force you exerted in steps 8-9 and in step 13. Record your observations.

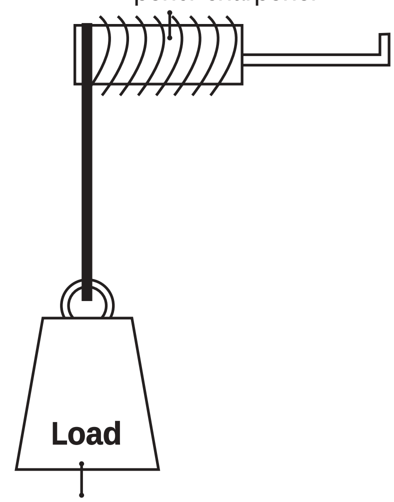


Diagram 1

Conclusion

1. Describe the simple machines used and explain how they work together.
2. How much did the force increase when the crank arm was extended?
3. You exerted less force in step 13. What is the trade-off?
4. List and describe other machines in everyday life that use a crank to make lifting easier.

Fighting Force of Friction

Materials

spring scale
4 different soled shoes
various sized washers
waxed paper
sandpaper
tape
balance

Purpose

To learn how different materials can affect friction
To investigate the amount of force needed to move an object

Background

Friction happens when objects rub together. As the tree house detectives calculate the force needed to get Jacob into the tree house, they have to consider friction as an opposing force. The ropes rubbing against the pulleys cause friction that must be overcome. Though friction is always a factor in the amount of force needed to move objects, there are ways that friction can be reduced so that the amount of force needed is also reduced.

Procedure

1. Measure 30 cm of waxed paper. Tape the paper to a flat surface such as a table.
2. Measure 30 cm of sandpaper. Tape the sandpaper along the side of the waxed paper.
3. Label the shoes from A-D.
4. Using a balance, find the mass of each shoe and record.
5. Determine which shoe has the most mass and calculate how much mass needs to be added to the other shoes to make them all equal.
6. Use the balance to find the number of washers needed to add to each shoe so that they are all of equal mass.
7. Place the correct number of washers in each shoe.
8. Place the toe of shoe A on the far edge of the waxed paper and connect the spring scale to the heel of the shoe. See diagram 1.
9. Making sure that the spring scale is parallel to the flat surface, slowly pull the shoe forward across the waxed paper.
10. Read the measurement on the spring scale just as the shoe begins to move and record in data chart.
11. Repeat steps 8-10 using the sandpaper.
12. Repeat steps 8-10 with each of the different shoes.
13. Rate your shoes from the ones that required the least amount of force to move to those that required the most force.

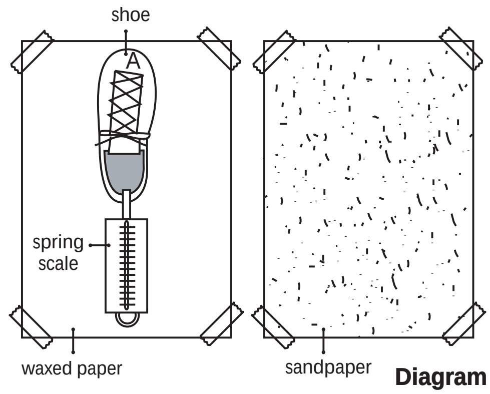


Diagram 1

Data Chart

				Force on Flat Surface	
Shoe	Type of Sole	Mass	Number of Washers Needed	Waxed Paper	Sandpaper
A					
B					
C					
D					

Conclusion

1. What are some differences in the shoes that required more force to those that required less force?
2. How do the soles of some shoes create more friction than others?
3. How did the force required for each shoe differ between the waxed paper and the sandpaper?
4. Which shoe required the least amount of force? Why?
5. Usually friction is thought of as a negative force that must be overcome to do work. What are some positive characteristics of friction in daily life?

Extension

1. Gather each group's results and create a class chart or graph. Analyze and discuss the findings.
2. Use shoe boxes and add water, oil, salt, and so on to the waxed paper to determine the difference in the amount of force needed.

Simply Words

Word Bank

inclined plane, screw, wedge, pulley, wheel and axle, fulcrum, load
force, lever, kinetic, potential energy, crank, winch, work
gears, teeth, machine, compound, friction, push, pull
apparatus, system

I	N	C	L	I	N	E	D	P	L	A	N	E	A	P	P	A	R	A	T	U	S
S	N	M	O	S	P	S	M	F	I	B	A	B	E	H	U	G	U	Y	I	N	I
G	A	C	A	M	O	R	P	D	O	V	C	A	C	X	L	R	O	L	M	D	T
I	B	F	D	E	P	E	R	I	A	K	M	E	I	C	L	I	P	E	O	E	P
P	N	S	A	A	I	O	M	B	N	H	T	I	H	B	E	L	C	H	T	R	O
F	H	E	D	L	T	I	U	A	I	R	A	U	X	S	Y	L	I	S	H	R	T
G	K	A	I	W	O	R	K	N	K	I	N	E	T	I	C	I	I	I	Y	O	E
C	J	I	L	I	E	S	N	M	D	C	J	I	L	P	L	L	E	U	D	O	N
B	L	S	T	Y	I	D	J	T	Y	B	L	S	T	U	T	A	G	O	R	F	T
Z	A	I	E	H	E	R	G	E	H	Z	A	I	E	S	I	R	V	A	I	M	I
S	S	M	W	E	T	I	P	E	I	T	E	E	T	H	S	C	A	R	E	D	A
Q	Z	Q	U	I	C	K	I	A	T	O	M	M	Y	F	R	T	E	P	U	L	L
R	N	L	D	S	H	I	N	D	F	R	I	C	T	I	O	N	I	T	I	X	E
Y	G	E	A	R	S	Z	A	I	O	V	C	O	U	R	T	N	E	Y	A	I	L
K	I	V	N	R	T	S	S	M	R	P	I	D	N	A	I	E	N	D	J	K	E
J	S	E	Y	K	O	Q	Z	Q	C	Y	I	Y	I	I	M	W	N	B	O	N	I
H	F	R	T	J	B	S	C	R	E	W	P	E	L	L	A	A	I	I	D	A	U
P	E	N	E	R	G	Y	A	E	R	T	R	K	C	I	L	A	C	S	T	R	Y
U	E	R	E	P	G	S	I	D	K	Z	U	A	A	E	R	I	S	H	I	C	T
Y	K	O	T	I	I	T	G	A	D	T	B	I	E	B	I	L	L	I	I	I	S
T	J	B	E	S	B	E	K	I	S	R	I	H	Y	O	T	J	A	C	O	N	I
S	A	E	M	A	I	M	O	H	T	A	W	P	F	I	S	L	I	Z	Q	U	E
I	G	W	I	N	C	H	E	N	N	Y	N	I	K	K	I	N	Y	I	R	P	V
O	F	A	E	B	Z	X	R	Q	W	R	O	R	L	F	U	L	C	R	U	M	E

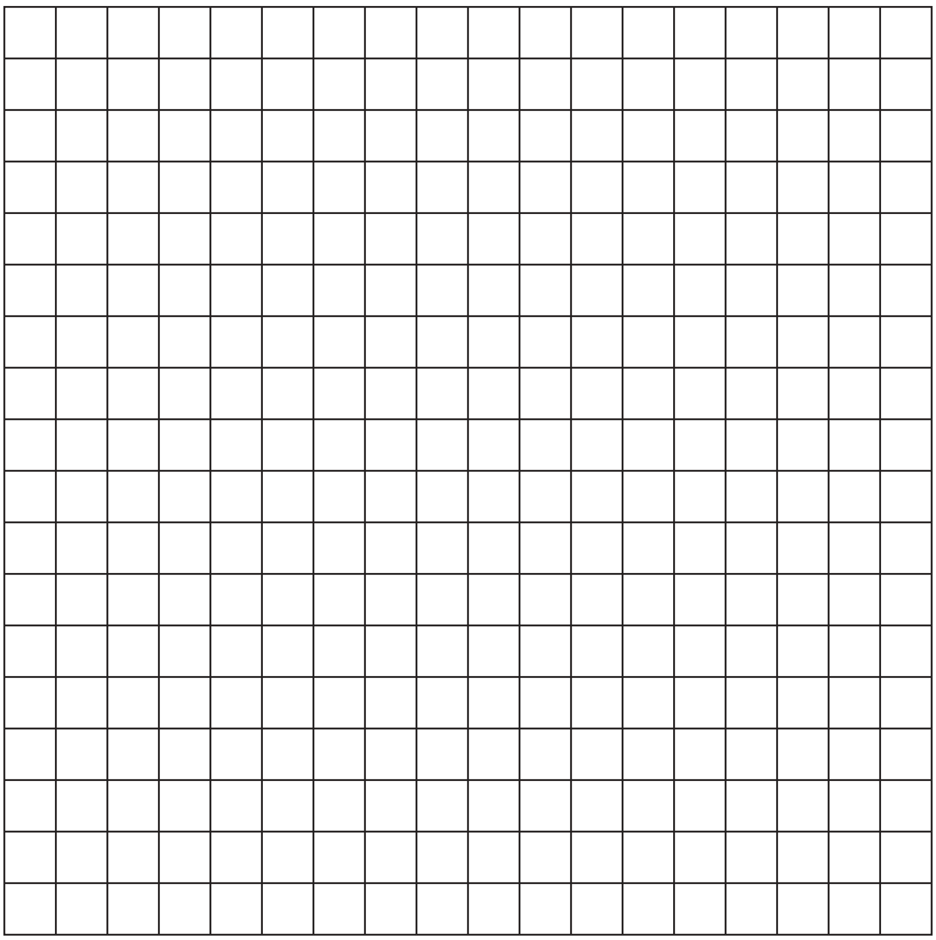
Vocabulary Crossword Puzzle

Create your own crossword puzzle using the key science vocabulary words from the program.

Vocabulary

inclined plane	screw	wedge	pulley	wheel and axle	fulcrum	force
lever	kinetic energy	potential energy	gears	friction		

Some of your own: ____



Down

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10. ____________________
11. ____________________
12. ____________________
13. ____________________

Across

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10. ____________________
11. ____________________
12. ____________________
13. ____________________

Answer Key

Get Your Gears Here!

1. The two smaller gears also turned. The smallest and middle gear turned more than the largest gear.
2. The middle gear turned in the opposite direction of the largest gear, and the smallest gear turned in the same direction as the largest gear.
3. The smallest gear.
4. More slowly.
5. Students should see that if you have twice the number of teeth on the larger gear than on the smaller gear, then the smaller gear will turn twice as fast, thus the speed of the gear doubles.

Crank It Up!

1. The simple machines used here are a wheel and axle and a lever. A crank is the handle that is connected to the axle. It is used to transmit motion.
2. The force was increased.
3. The trade-off is that you exerted the lower force over a greater distance as you moved through a greater circle. However, you did the same amount of work.
4. Answers will vary.

Fighting Force of Friction

1. Answers will vary, but should focus on the difference in the soles of the shoes.
2. A heavy, textured sole such as a cleat would create more friction than a smooth leather sole.
3. The smooth texture of the waxed paper decreased the amount of friction between the sole of the shoe and the waxed paper. A decrease in friction also caused a decrease in the force needed to move the shoes. Due to the rough texture of the sandpaper, friction increased; therefore, the amount of force needed also increased.
4. Answers will vary. Answers should focus on the soles of the shoes, the type of material the sole is made of, and the texture of the sole (cleat, roller blade, leather sole, rubber sole, and so on).
6. Answers will vary but might include tire treads that are used to grip a slippery road and the friction required to keep an elevator from slipping.

Simply Words