Pulleys: Groovy Wheels

BROWARD COUNTY ELEMENTARY SCIENCE BENCHMARK PLAN

Grade 3—Quarter 3
Activity 28

SC.C.1.2.1
The student understands that the motion of an object can be described and measured.

SC.H.1.2.1
The student knows that it is important to keep accurate records and descriptions to provide information and clues on causes of discrepancies in repeated experiments.

SC.H.1.2.2
The student knows that a successful method to explore the natural world is to observe and record, and then analyze and communicate the results.

SC.H.1.2.3
The student knows that to work collaboratively, all team members should be free to reach, explain, and justify their own individual conclusions.

SC.H.1.2.4
The student knows that to compare and contrast observations and results is an essential skill in science.

SC.H.1.2.5
The student knows that a model of something is different from the real thing but can be used to learn something about the real thing.

SC.H.3.2.2
The student knows that data are collected and interpreted in order to explain an event or concept.

ACTIVITY ASSESSMENT OPPORTUNITIES

The following suggestions are intended to help identify major concepts covered in the activity that may need extra reinforcement. The goal is to provide opportunities to assess student progress without creating the need for a separate, formal assessment session (or activity) for each of the 40 hands-on activities at this grade level.

1. Tell students that both pulleys and gears are wheels. Ask, How are pulleys and gears similar, and how are they different? (Pulleys have grooves, and gears have teeth. Both are circles that rotate around a center point, but pulleys have a fixed axle and gears move around on an axle. Both can be used to change the direction of an applied force.)
2. Use the Activity Sheet(s) to assess student understanding of the major concepts in the activity.

In addition to the above assessment suggestions, the questions in bold and tasks that students perform throughout the activity provide opportunities to identify areas that may require additional review before proceeding further with the activity.
OBJECTIVES

Students are introduced to a third type of simple machine: the pulley.

The students

- make a single, fixed pulley and use it to lift a load
- observe that a fixed pulley reverses the direction of applied force
- make a single, movable pulley and use it to lift a load
- observe that a movable pulley reduces the amount of force required to lift a load

SCHEDULE

About 1 hour

VOCABULARY

groove
pulley

MATERIALS

For each student

1 Activity Sheet 28, Parts A and B
1 pr safety goggles*

For each team of four

1 book, heavy*
1 dowel, wooden
2 plastic rings
1 pulley
1 push-pull meter
2 rulers, dual-scale*
1 pair scissors*
1 set washers, stacked and taped (from Activity 26)

For the class

1 roll masking tape
1 ruler, dual-scale*
1 pair scissors*
1 roll string
Delta Science Reader Force and Motion

*provided by the teacher

PREPARATION

1 Make a copy of Activity Sheet 28, Parts A and B, for each student.

2 For each team of four, cut a length of string 1.5 m (about 60 in.) long.

3 Each team will need two plastic rings, a length of string, a dowel, a heavy book, a pulley, a push-pull meter, two rulers, a pair of blunt-tip scissors, a stack of washers (taped together), and several pieces of masking tape. If you left the lengths of string tied to the washer stacks after Activity 25, keep that setup. (Replace any push-pull meter rubber bands that have become stretched.)

BACKGROUND INFORMATION

A pulley is another type of simple machine (see Figure 28-1). A pulley consists of a grooved wheel that spins around a stationary axle. A rope (or chain) rests in the groove of the wheel. Pulling on one end of the rope causes it to move over the wheel. The wheel turns easily as the rope rides in the groove.

Pulleys are used to help us move objects more safely and easily. Some pulleys work by changing the direction of applied force.
Others work by reducing the amount of force it takes to move a heavy object.

There are two types of pulleys: fixed and movable. A fixed pulley is one that does not move. This type of pulley makes it easier to lift an object by allowing you to pull down in order to raise a load. It is easier to pull down than to push up because your own weight and gravity help you (but it does not change the amount of force needed).

A movable pulley is one that moves along the rope as the rope is pulled. In this system, one end of the rope is firmly attached to a stationary object, and the pulley is attached directly to the load. A movable pulley reduces the amount of force you need to lift the load by half. That is because half of the weight of the load is supported by the stationary object (in this activity, a desk) and half is supported by you. The tradeoff is that the rope must be pulled twice as far in order to get the load to move half as much.

Using more than one pulley—called a block and tackle—can also reduce the amount of force it takes to lift a load. The more pulleys added to the system, the less force it takes to lift the load, but the farther the rope must be pulled.

In this activity, students build a single, fixed pulley and a single, movable pulley and observe how each type of pulley helps make work a little easier.

### Activity Sheet 28, Part A

**Pulleys: Groovy Wheels**

1. How is a pulley like a wheel and axle?
   
   They both have a wheel with an axle through the center of it.

2. How is a pulley different from a wheel and axle?
   
   Wheels and axles are attached and they turn together. A pulley wheel spins around its axle.

3. Look at the picture. Draw an arrow to show which direction you pull on the string. Then draw an arrow to show which direction the load moves when the string is pulled.

4. How much force does it take to lift the washers by hand?
   
   about 3–4 units

5. How much force does it take to lift the washers with a single, fixed pulley?
   
   about 4 units

6. How does a single, fixed pulley make it easier to lift a load?
   
   It reverses the direction of the force. It is easier to pull down on something than it is to lift or pull it up.

### Activity Sheet 28, Part B

**Pulleys: Groovy Wheels**

7. Look at the picture. Draw an arrow to show which direction you pull on the string. Then draw an arrow to show which direction the load moves when the string is pulled.

8. How much force does it take to lift the washers with a single, movable pulley?
   
   about 1½ to 2½ units

9. When you pulled the string 12 inches, how far did the load move?
   
   about 6 inches

10. How does a single, movable pulley make it easier to lift a load?
    
    by reducing the amount of force needed to lift the load

11. What is the tradeoff when using a single, movable pulley?
    
    The force must be applied over twice the distance. The string must be lifted twice as far as the load is lifted.
Distribute a copy of Activity Sheet 28, Parts A and B, to each student. Divide the class into teams of four, and distribute a pulley to each team. Give students time to examine the pulley. Ask students if they know what the object is.

Write the word pulley on the board. Tell students that this device is a pulley. Ask students to compare the pulley to a wheel and axle. Tell them to write their responses to questions 1 and 2 on the activity sheet. Then review their answers as a class.

Bring students’ attention to the groove around the rim of the pulley wheel. Write the word groove on the board and ask, What do you think this groove is for?

Ask, Where have you seen pulleys used?

Tell students that in this activity, they are going to learn how pulleys can help them do work.

Distribute a push-pull meter, a plastic ring, a dowel, a length of string, a stack of washers (taped together), two rulers, a heavy book, and several pieces of masking tape to each team. Tell teams that they are going to use these objects to build a pulley system.

Point out that Activity Sheet 28, Parts A and B, show the setups for two pulley systems. First they will build the single, fixed pulley system shown on Part A.

To begin, tell students to insert the dowel into the loop at the top of the pulley wheel. (It should fit snugly and slide in about an inch; circulate and provide help as needed.) Then have students tape the other end of the dowel to a desktop. Two 10-cm (3- or 4-in.) pieces of tape will be sufficient. The pulley should hang over the edge of the desktop. Have students place the book on top of the dowel for added security.

Like a wheel and axle machine, a pulley contains a wheel with an axle through the middle of it. Unlike a wheel and axle machine, in which the wheel and axle move as a single unit, a pulley wheel rotates freely around its fixed axle.

Some students may know that a rope, chain, or line of some sort sits or slides in the groove.

Students may have seen pulleys used on flagpoles, clotheslines, and adjustable ladders, in automobile repair shops, on elevators, and on cranes.

Note: To assure a secure fit of the pulley on the dowel, wrap the end of the dowel with a layer of masking tape.
Next, have students tie one end of the string around the stack of washers. (Thread the string through the middle of the washers, then tie it.) With the washers resting on the floor, have them thread the other end of the string through the pulley wheel so that it rests in the groove.

Finally, tell students to tie the free end of the string to the plastic ring. The completed pulley system should look like the one in Figure 28-2.

Ask students, **How can you use this pulley system to raise the load of washers?**

Tell students to pull on the ring at the end of the string and observe what happens. Ask, **What happens to the wheel inside the pulley when you pull on the string?**

Ask, **What happens to the washers when you pull down on the string?**

Ask, **When you raised the washers, did the pulley move or stay in the same place?**

Tell students that this type of pulley system is called a single, fixed pulley system. It’s called “single” because there is only one pulley. It’s called “fixed” because it does not move while it is being used.

Now ask, **In what direction did you pull the string?**

Ask, **In what direction did the washers move?**

Ask, **What does a single, fixed pulley do to the direction of the force you apply to the string?**

Tell students to complete question 3 on the activity sheet.

**Additional Information**

The washers may already be tied, following Activity 25.

![Figure 28-2. A single, fixed pulley system.](image)

Students should suggest pulling down on the free end of the string.

The wheel turns as the string moves over it.

Students should observe that pulling down on the ring end of the string causes the stack of washers to be lifted off the floor.

It stayed in the same place.

Guide students to understand that a single, fixed pulley changes (reverses) the direction of applied force.
### Guiding the Activity

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
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<tbody>
<tr>
<td>4</td>
<td>Ask students to pull down on the string again, this time noting the distance that the free end of the string and the load of washers each move. To verify their observations, have students measure the distance each end moves, using two rulers. Tell students to pull down on the string 6 inches and measure the distance that the washers are lifted. Then ask, <strong>Does one end of the string move farther than the other in a single, fixed pulley system?</strong></td>
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<td>5</td>
<td>Now ask students, <strong>Does using a single, fixed pulley decrease the amount of force you need to lift the washers?</strong> Have students remove the washers and string from the pulley system. Tell them to hook the plastic ring to the push-pull meter and use the meter to measure the amount of force it takes to lift a load of washers straight off the ground. Tell them to record the amount in question 4 of the activity sheet. Ask, <strong>Do you think it will take more force, less force, or the same amount of force to lift the washers using a single, fixed pulley?</strong></td>
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<td>6</td>
<td>Tell students to untie or unloop the string from the plastic ring and thread the string back through the pulley wheel as before. Have students reattach the string to the ring on the push-pull meter. Tell students to pull down on the push-pull meter to raise the load of washers. Tell them to note the amount of force it takes to lift the washers using the pulley (see Figure 28-3). Have them record the amount in question 5 of their activity sheets.</td>
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### Additional Information

- **They seem to move the same distance.**
- **Students should observe that the washers moved 6 inches as well.**
- **No. Guide students to understand that pulling down on the string causes the load to rise the same distance.**
- **Accept all reasonable answers.**
- **It should take about 3 to 4 units of force.**
- **Students may predict that it will take less force. Accept all answers.**

![Figure 28-3. Measuring the amount of force it takes to lift a load with a single, fixed pulley.](image-url)
When students have finished, ask, Did it take more force, less force, or the same amount of force to lift the washers with the pulley system?

Ask, If it takes about the same amount of force to lift a load with or without the pulley, what do you think is the advantage of using a single, fixed pulley system? Tell students to answer question 6 on the activity sheet.

Ask, How can we use a pulley to reduce the amount of force it takes to lift a load?

Tell students that the next type of pulley system will show them how.

Tell students to refer to Activity Sheet 28, Part B. Question 7 includes the setup for the second pulley system. Students should remove the pulley from the end of the dowel and remove the washers and string from the pulley system.

Distribute a pair of blunt-tip scissors and another plastic ring to each team, and tell students to cut the string that is tied around the stack of washers just above the knot. (This will leave a loop of string still tied around washers.)

Have them hook the second plastic ring to the string that remains tied around the washers. Have them attach the ring to the loop on the pulley wheel.

Next, tell students to tape one end of the long piece of string to their desks and place a book on it for security. Finally, they should thread the other end of the string through the pulley wheel. The completed setup should look like that in Figure 28-4.

Students should have discovered that it took about the same amount of force to lift the washers with the single, fixed pulley as it did to pick them up directly, without the pulley.

Note: It may take slightly more force due to friction. If this occurs, discuss with students the presence of friction in the pulley system.

The advantage is that it seems easier to pull down on something than to pull up on it or carry it to a height. This is due not only to how our bodies are built, but to the force of gravity working in our favor. Review the concept of gravity with students, if necessary. The fixed pulley also reverses the direction of the force.

Accept all reasonable answers.
## Guiding the Activity

| 8 | **Ask students, How is this pulley system similar to the single, fixed pulley you just built?**  
|   | Ask, **How is this pulley system different from the other one?**  
|   | **Ask students, How can you use this pulley system to raise the load of washers?**  
|   | Have students pick up the free end of the string, pull it straight up, and observe what happens to the washers.  
|   | **Ask, When you raised the washers, did the pulley move or stay in the same place?**  
|   | Tell students that this type of pulley system is called a single, movable pulley system. Like the other pulley system, it contains a single pulley wheel. It’s called “movable” because the pulley wheel moves along with the load.  
|   | **Now ask, In what direction did you pull the string?**  
|   | **Ask, In what direction did the washers move?**  
|   | **Ask, How is this different from the fixed pulley?**  
|   | Tell students to complete question 7 on the activity sheet.  
| 9 | **Ask students to recall how much force it took to lift the washers with a push-pull meter. (See the answer to question 4 on the activity sheet.)**  
|   | **Now ask students, Do you think it takes more force, less force, or the same amount of force to lift the washers using a single, movable pulley?**  
|   | Tell students to hook the plastic ring at the end of the string to their push-pull meter and pull up on the meter to raise the washers. Tell them to note the amount of force it takes to lift the washers using the pulley (see Figure 28-5). Have them record the amount in question 8 of the activity sheet.  

## Additional Information

- **Both types of pulley systems use just one pulley wheel.**
- **In this system, the load is attached directly to the pulley.**
- **Students should suggest pulling up on the free end of the string.**
- **The washers are lifted off the floor.**
- **It moved; it was lifted with the load.**
- **In a fixed pulley system, the force changes direction. In a movable system, the direction of force stays the same. The load moves in the same direction as the applied force.**
- **It took between 3 and 4 units of force.**
- **Accept all answers.**

![Figure 28-5. Measuring the amount of force it takes to lift a load with a single, movable pulley.](image)
## Guiding the Activity

When students have finished, ask, **Did it take more force, less force, or the same amount of force to lift the washers with this pulley system?**

Ask, **Why do you think it took less force?**

Remind students that with every decrease in force, there is a price to pay in distance.

Tell students to unhook the plastic ring from the push-pull meter. Have them use the ring to pull up on the string again, this time noting the distance that the free end of the string and the load of washers each moves.

To verify their observations, have students measure the distance each end moves, using two rulers. Tell students to pull up on the string 12 inches and measure the distance that the washers are lifted. Tell them to write their answers on question 9 of the activity sheet.

Then ask, **Does the free end of the string move farther than the load in a single, movable pulley system?**

Tell students to complete their activity sheets. Then review their answers as a class. Ask, **How does using a single, movable pulley help you lift a load?**

Ask, **What is the tradeoff when using a single, movable pulley?**

As appropriate, read or review pages 2–5 and 8 of the Delta Science Reader *Force and Motion.*

## Additional Information

**Students should have discovered that it took less force (about half as much) to lift the washers with the single, movable pulley as it did to pick them up directly, without the pulley.** Because half of the weight of the washers is supported by the string hanging from the desk.

**The ring end of the string seems to move about twice as far as the washers do.**

**Students should observe that pulling up on the string a distance of 12 inches causes the washers to rise only about 6 inches.**

Yes. The string must be pulled twice as far in order to get the load of washers to move half as far.

Using a single, movable pulley to move a load reduces the amount of force needed by half.

The force must be applied over twice the distance.
Challenge students to build fixed and movable pulley systems without using the metal pulley wheels.

To build a fixed pulley system, simply have students toss the string over the dowel that is taped to the edge of their desk. When they pull down on the free end of the string, the load at the other end will rise.

To build a movable pulley, have students replace the pulley with a plastic ring. When the free end of the string is pulled up, the ring and the load of washers to which it is attached will rise also.

Ask students, What is the danger in using a pulley system without a pulley wheel? (Answer: Friction over time can cause the string to break. The wheel inside a pulley wheel assembly reduces friction by turning as the string moves over it.)

Assessment Opportunity
This Reinforcement also may be used as an ongoing assessment of students’ understanding of science concepts and skills.

Have students place their completed activity sheets in their science journals.

Return the push-pull meters, stacks of washers, dowels, pulleys, plastic rings, and rolls of string and tape to the kit. Discard the lengths of string, but leave the loop of string tied around the washer sets.
**Science Challenge**

- Introduce the concept that several pulleys can be used together in a single system. Have students work in small groups to experiment with arrangements of two, three, or more pulleys to lift a load. What effect does increasing the number of pulleys have on the amount of force required? (The more pulleys there are, the less force is required.) What is the tradeoff in using more pulleys? (The force must be applied over a greater distance.)

- Invite students to speculate about what eventually happens to the rope of a pulley system and why. (The rope becomes worn and would break if not replaced because of friction between the rope and the pulley.)

**Science Extension**

- If your school has a flag on an outside flagpole that is raised and lowered at the beginning and end of the school day, try to arrange a time when your class can be outside to observe this event. Direct students’ attention to the pulley that enables the flag to be raised and lowered easily.

- Have students look for examples of pulleys being used in daily life. Among others, they may note the use of pulleys on clotheslines and cranes.

**Science and the Arts**

Students should now add examples of pulleys to their ongoing bulletin board display of simple machines. You may wish to provide actual pulleys, which are available in hardware and building supply stores and hardware departments of other stores.

**Science, Technology, and Society**

- The block and tackle is a system of pulleys that is compact and yet able to raise substantial loads. It is commonly used at the end of a crane’s boom to increase the force of the crane’s motor in lifting a load. A block and tackle system consists of one rope wound around two separate sets of pulleys. The pulleys in each set are free to rotate independently on the same axle. The upper set is attached to a support. The lower set is attached to the load. Pulling the rope raises the lower set of pulleys. The magnification of the force that the block and tackle produces is equal to the number of pulley wheels it contains. Encourage students to research and report on this use of the pulley. Some students may also enjoy finding out how pulleys are used in combination with a motor and a counterweight to operate an elevator.

- Students can experience the effect of a simple block and tackle by carrying out the following activity in groups of three. Each group will need 2 brooms (or anything with a long pole) and a strong rope or clothesline at least 9 ft (3 m) long. As two students hold the poles about 1 ft (30 cm) apart, the third tries to pull them together. The student will not be able to succeed. Next, have the third student tie one end of the rope securely around one of the poles and wind the other end several times around the other pole. The student, pulling on the free end of the rope, should be able to draw the poles together. Point out that winding the rope increases the force of the pull—in fact, every turn of the rope approximately doubles the pulling power. Guide students to recognize the tradeoff—every time the force is increased, so is the distance required to pull the free end of the rope.