

SECTION 3.4 INTRODUCTION

3.4 Investigate

◀ 2 class periods*

How Do Pulleys Change a Force?**Overview**

Students investigate the mechanical advantage of a fixed pulley, a free pulley, and a combination of the two pulleys. Students are first introduced to the parts of a pulley. Then they sketch their predictions of the forces acting on a pulley system used in a flagpole. Groups then investigate the difference between fixed and free pulleys, and the combination of a fixed and a free pulley, paying attention to the force and distance required to lift a 1-kg mass 20 cm. Students analyze their measurements using graphs of their data. Then groups interpret the trends in their results to make claims about the mechanical advantage of fixed and free pulleys. Students share their analysis and conclusions during an *Investigation Expo*. This collaboration allows students to compare their results with others to consider the reliability of their measurements, look for general trends, and build on each other's ideas.



Students should wear closed-toe shoes.

*A class period is considered to be one 40 to 50 minute class.

Targeted Concepts, Skills, and Nature of Science	Performance Expectations
Scientists often work together and then share their findings. Sharing findings makes new information available and helps scientists refine their ideas and build on others' ideas. When another person's or group's idea is used, credit needs to be given.	Students should discuss the results of their investigation of the free and fixed pulleys during an <i>Investigation Expo</i> . Students should build on each other's ideas and results.
Scientists must keep clear, accurate, and descriptive records of what they do so they can share their work with others and consider what they did, why they did it, and what they want to do next.	Students should keep good records during their investigation so they can successfully analyze their data and share their results during the class's <i>Investigation Expo</i> .
Graphs and tables are an effective way to communicate results of scientific investigation.	Students record their data in tables and draw graphs.

Targeted Concepts, Skills, and Nature of Science	Performance Expectations
Scientific investigations and measurements are considered reliable if the results are repeatable by other scientists using the same procedures.	Students should determine if their measurements are reliable by comparing their trials. Students should also determine if their results are reliable by comparing their results with the results of all the groups.
In a fair test only the manipulated (independent) variable, and the responding (dependent) variable change. All other variables are held constant.	Students should be able to evaluate their investigation and others to determine if they are fair tests and describe why or why not they are.
Scientists make claims (conclusions) based on evidence obtained (trends in data) from reliable investigations.	Students should make claims about the mechanical advantage of levers based on the trends in their data.
Explanations are claims supported by evidence, accepted ideas, and facts.	Students should construct explanations about the mechanical advantage of pulleys based on the trends in their data.
Machines provide mechanical advantage to assist in moving objects. Mechanical advantage is the tradeoff between force and distance.	Students should make claims about the mechanical advantage of pulleys, realizing that for the fixed pulley the mechanical advantage ideally is one and for the free pulley it is two, requiring half the force but twice the distance to lift the load.
There are six different simple machines all of which provide mechanical advantage: Inclined plane, wedge, screw, wheel and axle, lever, and pulley	Students should be able to describe the mechanical advantage of free and fixed pulleys.

Materials

- 1 per group spring scale (0-20 N)
- 2 per group metric ruler
- 1 per group 1-kg mass
- 2 per group pulleys
- 1 per group about 100 cm of string
- 1 per group ring stand
- 1 per group 3 inch bolt and wing nut
- 1 per student *Recording Your Data* page

Materials (continued)

- 1 per student** *Average Force Measurement* page and *Average Distance Measurement* page
- 1 per student** *Create Your Explanation* page
- 1 per classroom** *Flagpole Construction* BLM

META NOTES

It is important for students to measure and record the distance through which they apply the force, not the distance through which the 1-kg mass is pulled (as indicated in the student text). The 1-kg mass is pulled a fixed distance of 20 cm for each measurement.

Activity Setup and Preparation

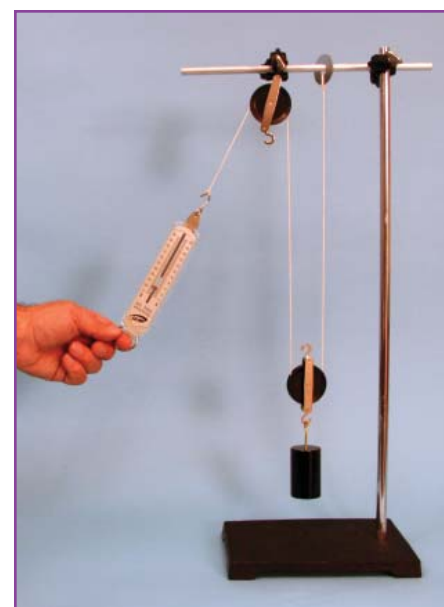
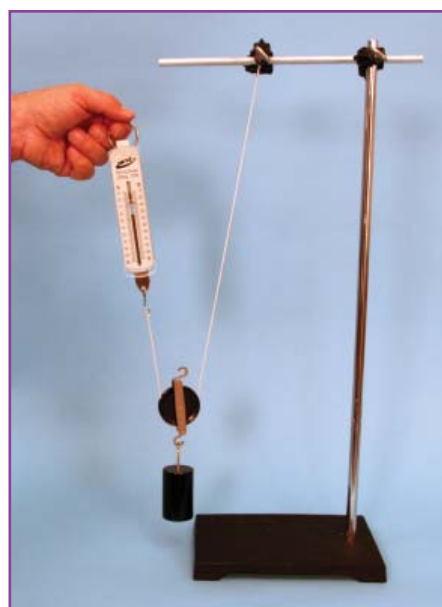
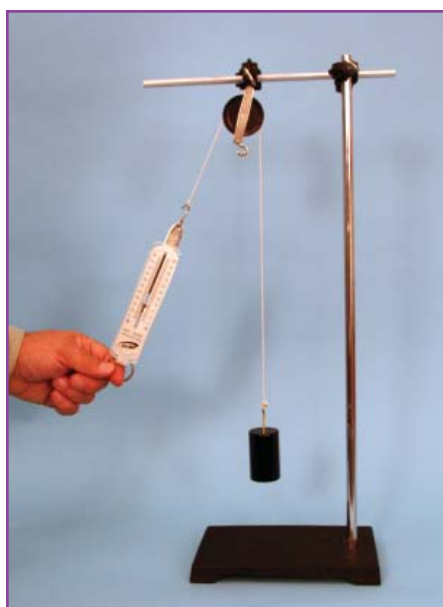
Decide if you will take the class to see the pulley system in a flagpole. You will need binoculars for the students to see the pulley systems.

Consider your timing. A good place to break the activity in order to spread it over two class periods, is after the *Stop and Think* segment, before the second *Predict* segment.

You should have a setup of the equipment to show to the class. You may want to set up the student materials in advance. Images of the setup for a fixed, a free, and a combination of fixed and free pulleys are shown below.

The head end of the 3" screw should be clamped into one of the right angle holders on a ring stand. In this location it can act as a locator pin for a vertical fixed pulley.

Run the experiment to determine where your students may have difficulty with setting up the equipment or taking measurements. Consider marking the 20 cm high point for the mass on the ring stand (for example, with colored tape, sticky paper, or a clothes pin).



SECTION 3.4 IMPLEMENTATION

◀ 2 class periods*

3.4 Investigate**How Do Pulleys Change a Force?**

A mechanic may use pulleys to remove an old engine from a car.



pulley: a simple machine made up of a wheel with a groove that holds a rope.

fixed pulley: a pulley in which the shaft that the wheel rotates around (axle) does not move.

free pulley: a pulley in which the shaft that the wheel rotates around (axle) can move.

A **pulley** is another example of a simple machine. It is made of a wheel and something to pull on, such as a rope or chain, laid over the wheel. When the rope moves, the wheel turns. A pulley can make lifting something much easier.

Pulleys are very important simple machines. They are used often. They may be used to move light things such as flags or window blinds. They are also used to move heavy things such as boats or elevator cars.

In this investigation, you will answer the question *How do different arrangements of pulleys help you move a weight?*

Predict

Before you start your investigations, think about the other simple machines you have used to lift a weight. Sketch a flagpole pulley system. You can do this from memory or find a flag pole to copy. Then predict and mark the forces in the flagpole pulley system. Use force arrows to show the direction and size of each force.

Procedure

Just as before, you will begin by raising the weight from the table, straight up. This is the control so you know how much force is required to lift the block without using a simple machine. Then you will lift the weight to the same height using a variety of pulleys. You will measure the force required when you use a **fixed pulley**, a **free pulley**, and a machine that combines a fixed and free pulley.

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3.4 Investigate**How Do Pulleys Change a Force?**

5 min.

*Introduce pulleys.***Engage**

Ask students where they have seen pulleys and what they were used for. Record students' ideas and discuss them.

We've already explored the inclined plane, and the lever. What about the pulley that was mentioned earlier? Where have you seen pulleys being used and what were they used for?

If students did not bring up pulleys being used in flagpole to raise and lower a flag or window blinds to raise and lower the blinds, then discuss them.

Predict

10 min.

Have students sketch a force diagram of the pulley system in a flagpole.

META NOTES

Some students may show that a pulley changes the direction of a force, having seen changes of direction in the force diagrams of knives and wood splitters. Some students won't be familiar with pulleys and will draw the diagram incorrectly. This is O.K. Here students are putting down their initial ideas based on what they already know and they will understand more after doing the investigation. Predicting the forces on the pulley system based on what they have already learned about simple machines provides a good hook for students to build their ideas on.

Procedure

15 min.

Guide students through running the procedure and collecting data.

A mechanic uses pulleys to remove an old engine from a car.

pulley: a simple machine made up of a wheel with a groove that holds a rope.

fixed pulley: a pulley in which the shaft that the wheel rotates around (axle) does not move.

free pulley: a pulley in which the shaft that the wheel rotates around (axle) can move.



Procedure

Just as before, you will begin by raising the weight from the table, straight up. This is the control so you know how much force is required to lift the block without using a simple machine. Then you will lift the weight to the same height using a variety of pulleys. You will measure the force required when you use a **fixed pulley**, a **free pulley**, and a machine that combines a fixed and free pulley.

In this investigation, answer the question *How do different arrangements of pulleys help you move a weight?*

Predict

Before you start your investigations, think about the other simple machines you have used to lift a weight. Sketch a flagpole pulley system. You can do this from memory or find a flag pole to copy. Then predict and mark the forces in the flagpole pulley system. Use force arrows to show the direction and size of each force.

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△ Guide

Show students an image of the pulley used in a flagpole and if possible take students out to see the flagpole. You will need binoculars for the students.

Then have students sketch their predictions of where they think the forces are acting on a flagpole pulley system, indicating the size and direction of the forces in the diagram.

△ Guide

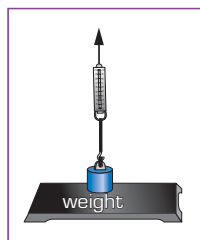
When students have finished drawing their flagpoles, let them know that each group will be running a four-part investigation into pulleys and recording their data. Let them know that for now the focus will be on the first three parts of the investigation.

Begin discussing the procedures for each of the first three parts of the investigation. Quickly let them know that the first part is what they have done before, just lifting the weight straight up without a pulley. This time they will lift it 20 cm. Then show students the setup for the second investigation of the fixed pulley (which is different than in the book). Emphasize that they will be measuring how much force is required to lift the 1-kg mass up 20 cm and what distance they must apply that force through to raise the 1-kg mass 20 cm. Demonstrate how to measure the distance and let them know that they should decide on what angle they want to pull the string. Ask students why it is important to pull at the same angle each time.

3.4 Investigate

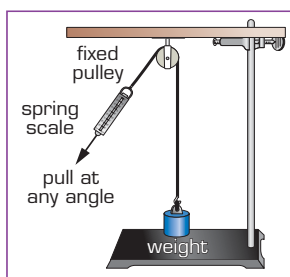
Part 1: Lifting the Weight without a Pulley

1. Use the diagram to help you set up your equipment correctly.
2. Attach the spring scale to the weight. Lift the weight 20 cm above the table using the spring scale. Measure 20 cm from the top of the table to the bottom of the weight.
3. The amount of force you used to lift the weight is shown on the spring scale. Read the amount of force in newtons (N) you used to lift the weight. Record that measurement on your data table.
4. On the data table, record the distance the weight moved as 20 cm.
5. Repeat this procedure in the same way two more times for a total of three trials. Record all the data on your data table.

**Part 2: Using a Fixed Pulley to Lift the Weight**

In this part of the investigation, you will use a fixed pulley to lift the weight 20 cm. The height you lift the weight will stay constant so you will be able to compare your force data to the force data for just lifting the block straight off the table. You will need to measure the distance you pulled to lift the weight 20 cm from the table.

1. Use the diagram to help you set up your equipment correctly. The pulley is fixed to the top of the stand and the string is over the top of the pulley. Put one meter stick next to the weight and measure 20 cm from the table. Hold the meter stick in this position.
2. Attach the spring scale to the string. Hang the weight from the other end of the string.
3. Put the other meter stick next to your hand. Be ready to measure how far you have to pull down on the string when the weight is raised 20 cm.
4. Pull down on the spring scale until the weight is 20 cm from the table.
5. The amount of force you used to lift the weight is shown on the spring scale. Read the amount of force in newtons (N) you used to lift the block. Record that measurement on your data table.
6. Use the ruler to measure how far up your hand moved to pull the weight up 20 cm. On the data table, record the distance your hand moved.

**Materials**

- spring scale (0 N–20 N)
- weight
- 2 pulleys
- string
- ruler
- ring stand
- scissors
- right-angle clamp
- screw
- 2 washers
- bolt (3 in.)
- wingnut

META NOTES

A good place to break over two class periods is after the *Stop and Think* segment. If you decide to break class periods at this point then students will run Part 4 of the investigation during the next class period.

META NOTES

This is a good place to assess and review students' understanding of fair tests.

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MOVING BIG THINGS

TEACHER TALK

“Why do you want to pull at the same angle each time? Do you want to do this for each trial? Across trials? Why?”

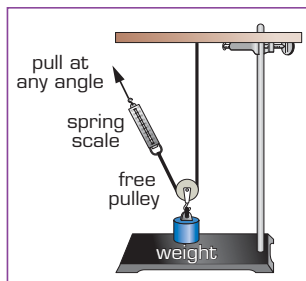
Then show them how to set up the free pulley system.

META NOTES

When groups finish the first three parts, they should work through the *Analyze Your Data* segment and then answer the *Stop and Think* questions.

- Repeat this procedure in the same way two more times for a total of three trials. Record all the data on your data table.

Part 3: Using a Free Pulley to Lift the Weight



In this part of the investigation, you will use a free pulley to lift the weight 20 cm. The height you lift the block will stay constant. You will need to measure the distance you pulled to lift the weight 20 cm off the table.

- Use the diagram to help you set up your equipment correctly. The pulley is able to move and the string is looped under the pulley. Put one meter stick next to the weight and measure 20 cm from the table. Hold the meter stick in this position.
- Attach the spring scale to the string. Attach the weight from the other end of the string.
- Put the other meter stick next to your hand, be ready to measure how far you have to pull up on the string to raise the weight 20 cm.
- Pull up on the spring scale until the weight is 20 cm from the table.
- The amount of force you used to lift the weight is shown on the spring scale. Read the amount of force you used to lift the weight. Record that measurement on your data table.
- Use the ruler to measure how far up your hand moved to pull the weight up 20 cm. On the data table, record the distance your hand moved.

Repeat this procedure in the same way two more times for a total of three trials. Record all the data on your data table.

Recording your Data

Use a table like the one below to organize your data.

Vertical lift		With fixed pulley		With free pulley		With fixed and free pulley	
Force to lift weight (N)	Distance weight is lifted (cm)	Force to pull weight (N)	Distance weight is pulled (cm)	Force to pull weight (N)	Distance weight is pulled (cm)	Force to pull weight (N)	Distance weight is pulled (cm)

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NOTE: Emphasize that it is important for students to measure and record the distance through which they apply the force, not the distance through which the 1-kg mass is pulled (as indicated in the student text) in the tables on pages 80 and 81. The 1-kg mass is pulled a fixed distance of 20 cm for each measurement.

Get Going

Distribute materials and have groups begin running their investigations. Let students know how much time they have.

Analyze Your Data

20 min.

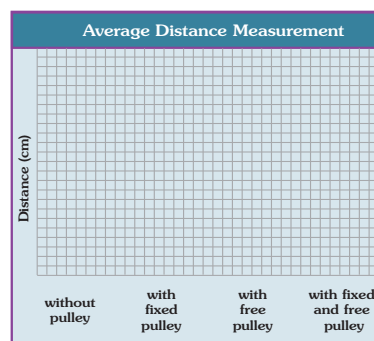
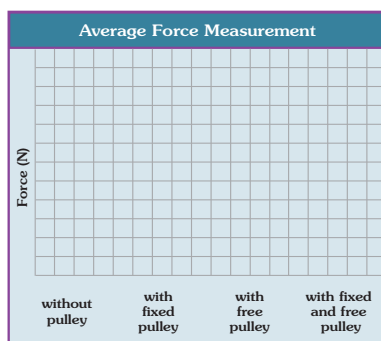
Have students graph and analyze their data for Parts 1 through 3.

3.4 Investigate

Vertical Lift		With Fixed Pulley		With Free Pulley		With Fixed and Free Pulley	
average force to pull weight (N)	average distance weight is pulled (cm)	average force to pull weight (N)	average distance weight is pulled (cm)	average force to pull weight (N)	average distance weight is pulled (cm)	average force to pull weight (N)	average distance weight is pulled (cm)

Analyze Your Data

You should now have data from lifting the weight straight from the table and then lifting it to the same height with two different pulleys. You will now analyze your data to see how the pulleys changed the size and direction of the force.



Force

Calculate the average force measurements for each part of the investigation. Create a bar chart using the average measurements for force. Bar one should be the lift straight off the table, bar two is the fixed pulley, and bar three is the free pulley. Make sure you have three bars on your chart when you are finished.

Distance

Calculate the average distance measurements for each part of the investigation. Create a bar chart using the average measurements for distance. Bar one should be the lift straight off the table, bar two is the fixed pulley,

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MOVING BIG THINGS

△ Guide

Let students know they should average their measurements for the three parts of the investigation they've done so far, and then graph the averages on the *Average Force Measurement* and *Average Distance Measurement* bar charts.

You should analyze your data as you did for the three parts of the experiment. First find the averages and then make bar charts of these averages. You should have two bar charts, one for the average force for each pulley, and one for the average distance for each pulley.

Stop and Think

10 min.

Hold a class discussion on students' understanding of free and fixed pulleys.

and bar three is the free pulley. Make sure you have three bars on your chart when you are finished.



Stop and Think

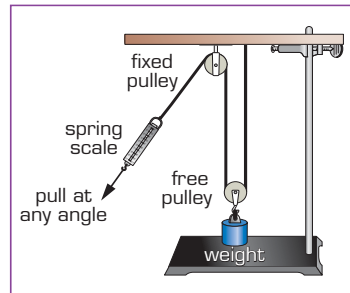
1. You have used two different types of pulleys to lift the same weight and they worked differently. Compare the two different pulleys. Explain how the forces changed when you used each pulley. Describe how the direction of the pull compared with the direction of the movement for each pulley.
2. Describe two situations in which you might want to use a fixed pulley and two situations in which you might want to use a free pulley.

Predict

You are now going to combine the fixed and free pulleys to see what happens when you use these two pulleys together. This is the first time you will use more than one simple machine to move the weight. Predict how you think the force and direction will be different when you use the two machines in combination. Record your prediction.

Procedure

Part 4: Combining a Fixed and Free Pulley to Lift the Weight



In this part of the investigation, you will use both a fixed and free pulley to lift the weight 20 cm. You will measure the force required to lift it 20 cm. You will also measure the distance you pulled to get the weight 20 cm off the table.

1. Use the diagram to help you set up your equipment correctly. The fixed pulley will hang from the top of the stand. The free pulley will move with the string.
2. Loop the string over the fixed pulley and under the free pulley. Make sure both ends of the string are free. Attach a spring scale to one end and the weight to the other end.
3. Put one of the meter sticks next to the weight and measure 20 cm from the table. Hold the meter stick in this position.

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△ Guide

Have groups complete the questions, then lead a discussion on their responses.

TEACHER TALK

“You investigated two different pulleys. How do they both compare to just lifting the mass straight up? How do the two pulleys compare to each other? How did your results compare to you predictions?”

As you discuss the *Stop and Think* questions, encourage students to use their data and the trends they found in their data to support their ideas. Guide students during the discussion toward the following ideas, highlighting the mechanical advantage of the two pulleys.

1. In comparing the two pulleys, students should note that the fixed pulley can change the direction of the force, but it doesn't change the amount of force required; it has a mechanical advantage of one. The free pulley requires about half the force and twice the distance. This means the free pulley has double the mechanical advantage of the fixed pulley. The fixed pulley changes the direction to the direction you are applying the force in. The free pulley also changes the direction of the force to the direction you pull. Window blinds have fixed pulley systems in them. Students should also compare their results with their predictions during the discussion.
2. Examples of situations where a fixed pulley would be used: Whenever you want to change the direction of a force but don't need to change the amount of force needed to move something. For example, if you want to lift something up to a tree house, lifting a bucket of sand to the top of a play structure, etc.

Examples of situations where a free pulley would be used: Velcro straps go through a slot and then fold over to "stick" to itself. The slot acts as a free pulley with a mechanical advantage of two. Some heavy drapery uses a free pulley system.

META NOTES

The ideal mechanical advantage for a fixed pulley is one and for a free pulley is two, however due to friction within the pulley system the actual mechanical advantage is less.

META NOTES

If you can plan your class to end with this discussion, it is a good way to wrap up the class period and then begin the next class period with the *Predict* segment below. Another good breaking point is at the end of the next *Analyze Your Data* segment.

direction of the pull. _____ in the direction _____ for each pulley.

2. Describe two situations in which you might want to use a fixed pulley and two situations in which you might want to use a free pulley.

Predict

You are now going to combine the fixed and free pulleys to see what happens when you use these two pulleys together. This is the first time you will use more than one simple machine to move the weight. Predict how you think the force and direction will be different when you use the two machines in combination. Record your prediction.

Procedure

Part 4: Combining a Fixed and Free Pulley to Lift the Weight

Predict

5 min.

Have students predict how the force and direction will change using a system of a free and fixed pulley combined.

Now that students have discussed fixed and free pulleys, have them predict what will happen when they combine a fixed pulley with a free pulley. Begin by showing them what the system looks like. Emphasize that this is the first time they are using more than one simple machine. And ask them to record their predictions on how this machine will affect the force needed to lift the 1-kg mass and the direction it will move in.

TEACHER TALK

“You’ve collected data and discussed how a fixed pulley affects the force applied—it changes the direction but not the amount. You’ve also found out that a free pulley requires half the force, and can change the direction. Let’s consider something new. What if we were to combine these two types of pulleys? What do you think would happen to the force needed? Would the amount change? Would the direction change? How? Think about that and write down your predictions.”

When students have written their predictions, lead a discussion of the different ideas students have. You might encourage an informal debate of what will happen. Students will not be able to make well-founded predictions, but this is a good opportunity for them to consider what might happen.

Procedure

5 min.

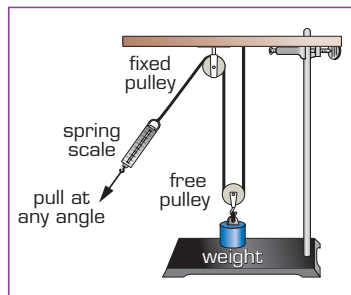
Describe the procedure and have students run the investigation of a combined pulley system.

META NOTES

If any groups are having a lot of trouble, consider having another group who got it help them.

Procedure

Part 4: Combining a Fixed and Free Pulley to Lift the Weight



In this part of the investigation, you will use both a fixed and free pulley to lift the weight 20 cm. You will measure the force required to lift it 20 cm. You will also measure the distance you pulled to get the weight 20 cm off the table.

1. Use the diagram to help you set up your equipment correctly. The fixed pulley will hang from the top of the stand. The free pulley will move with the string.
2. Loop the string over the fixed pulley and under the free pulley. Make sure both ends of the string are free. Attach a spring scale to one end and the weight to the other end.
3. Put one of the meter sticks next to the weight and measure 20 cm from the table. Hold the meter stick in this position.

△ Guide

Demonstrate for students how to set up this pulley system again. Emphasize that again students will be measuring how much force they need to apply and the distance that they have to apply that force in order to lift the 1-kg mass 20 cm. Remind them to pull at the same angle all the time and to record a description of the angle they are pulling at. Then distribute the materials, if necessary, and let students know how much time they have.

Analyze Your Data

10 min.

Have students graph and analyze their data for Part 4 and briefly discuss their results.

META NOTES

This discussion should be brief and without much guidance, as students will be discussing all their results during an *Investigation Expo*.

3.4 Investigate

- Put the other meter stick next to your hand. Be ready to measure how far you have to pull up on the string to raise the weight 20 cm.
- Pull up on the spring scale until the weight is 20 cm from the table.
- The amount of force you used to lift the weight is shown on the spring scale. Read the amount of force in newtons (N) you used to lift the block. Record that measurement on your data table.
- Use the ruler to measure how far up your hand moved to pull the weight up 20 cm. On the data table, record the distance your hand moved.
- Repeat this procedure in the same way two more times for a total of three trials. Record all the data on your data table.

Recording your Data

Record your data for this part of the investigation in your pulley table.

Analyze your Data

The fixed and free pulleys change force differently. Add the data for this part of the investigation to the bar charts you created earlier. Answer these questions.

- How was the force and distance different this time?
- How did the actual results compare to your prediction?
- How accurately did you predict the final results?
- What is the advantage of a pulley system that includes both a free and a fixed pulley?



A sailboat uses many different pulley systems.

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MOVING BIG THINGS

When groups have completed their measurements have them continue to the *Analyze Your Data* segment.

△ Guide

Once groups have run their investigations, have them complete their bar charts with the results from Part 4 of their investigation and answer the four questions in the student text. Briefly discuss students' results for questions 1 through 3, but keep question 4 for discussion during the *Investigation Expo*.

□ Assess

During the discussion, listen for the following:

1. Students should describe that the amount of force and distance needed were similar to that of just having the free pulley—half the force and twice the distance.
2. Students should describe how the force they predicted was different from their actual measurements.
3. Students should describe how different their predictions were from their actual observations.
4. The advantage is that by using the free pulley, you can reduce the amount of force and incorporating a fixed pulley into the system lets you change the overall direction.

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Communicate Your Results: Investigation Expo

15 min.

Guide students in preparing their posters and then have a class discussion after students have viewed all posters.



Communicate Your Results

Investigation Expo

When you are finished with your investigation, you will share your results with the class during an *Investigation Expo*. During an *Investigation Expo*, your group will present the procedure you followed, the data you obtained, and the meaning of your results. An investigation poster is one way to help you present and explain this information. As you are presenting to your classmates, they will want to understand

- What question were you trying to answer in the investigation?
- What procedure did you use and do you feel it was a fair test?
- What materials did you use?
- What is your interpretation of the results and how confident are you in them?

Make a poster that includes all five items listed above. Present them in a way that will make it easy for someone to look at your poster and identify what you have done and what you found out. If you think the test you ran was not as fair as you had planned, your poster should also have a report on how you would change your procedure if you had the chance to run the experiment again.



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Get Going

When students have finished graphing their data, distribute poster materials and have each group create a poster that answers all of the bulleted points on pages 84 and 85. Emphasize that they will need to describe if their experiment was a fair test. Did the investigation try to answer the question? What were the manipulated variable and the variable they measured in response to that change? What factors or variables did they try to keep the same? Did they follow the same procedures each time? And they will need

to discuss their data, analysis, and conclusions. Also, emphasize that they should make claims about the mechanical advantage of the fixed, free, and combination pulleys.

Once all groups have finished their posters, have each group put their poster up on the wall and allow all groups to review each poster for a minute or two.

△ Guide

After groups have reviewed the posters, if you selected groups to present their results, have them present now.

Then hold a class discussion. Focus the discussion on the reliability of results, general trends, conclusions of the investigations, mechanical advantage, and what students think they learned.

Begin the discussion by asking: “How close were everyone’s results?” If students haven’t brought them up on their own, this would be a good place to point out some of the differences you observed in the way groups were carrying out their procedures. Remind students of the importance of running procedures exactly.

Then ask “What trends did you notice?” and “What do these trends mean?”

Students should notice that the fixed pulley only changes the direction of a force and the free pulley changes the amount and direction of the force needed such that half the force is needed but over twice the distance.

Discuss the mechanical advantage of the pulleys and ask what students think they learned. Let students know that next they will be constructing explanations for the pulleys.

META NOTES

Note that all groups will be viewing the posters. You could have one or two groups present, or you could go directly into a class discussion of class’s results and conclusions. As groups are preparing determine if you want any groups to present and which ones. The discussion following presentations will focus on discussing mechanical advantage.

META NOTES

The ideal mechanical advantage for a fixed pulley is one and for a free pulley is two, however, due to friction within the pulley system the actual mechanical advantage is less.

NOTES

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Explain

5 min.

Have students construct explanations about the pulleys they investigated.

3.4 Investigate

Look for differences in how groups completed the investigation. Make sure the data seems consistent from one group to another. Be sure to point out any errors you see in procedure, variable control, or interpretation of the data.

As others present their work, look for answers to these questions:

- What was the group trying to find out?
- What variables did they control as they did their procedure?
- Is their data scattered or is it fairly consistent?
- Did they measure the force needed to lift the weight in a consistent way?
- Did their procedure cause them to run a poor, uncontrolled experiment?
- What did they learn?
- What conclusions do their results suggest?

Ask questions that you need answered to understand results and to satisfy yourself that the results and conclusions others have drawn are true. Be sure that you trust the results that other groups report.

Explain

You have written explanations of how two simple machines, the inclined plane and the lever, change the force required to move a weight. You just investigated a third type of simple machine, the pulley. Write an explanation of how pulleys can change force.

Recall that an explanation is made up of three parts:

- Claim—a statement of what you understand or a conclusion that you have reached from an investigation or set of investigations
- Evidence—data collected during investigations and trends in that data
- Science knowledge—knowledge about how things work. You may have learned this through reading, talking to an expert, discussion, or other experiences.

Do your best to explain the results of your investigation. Meet with your group to write an explanation of what happens to the force that must be applied as the fulcrum is moved closer to the weight. The *Create Your Explanation* page provides hints so that you'll remember how to put an explanation together.

MBT 85

MOVING BIG THINGS

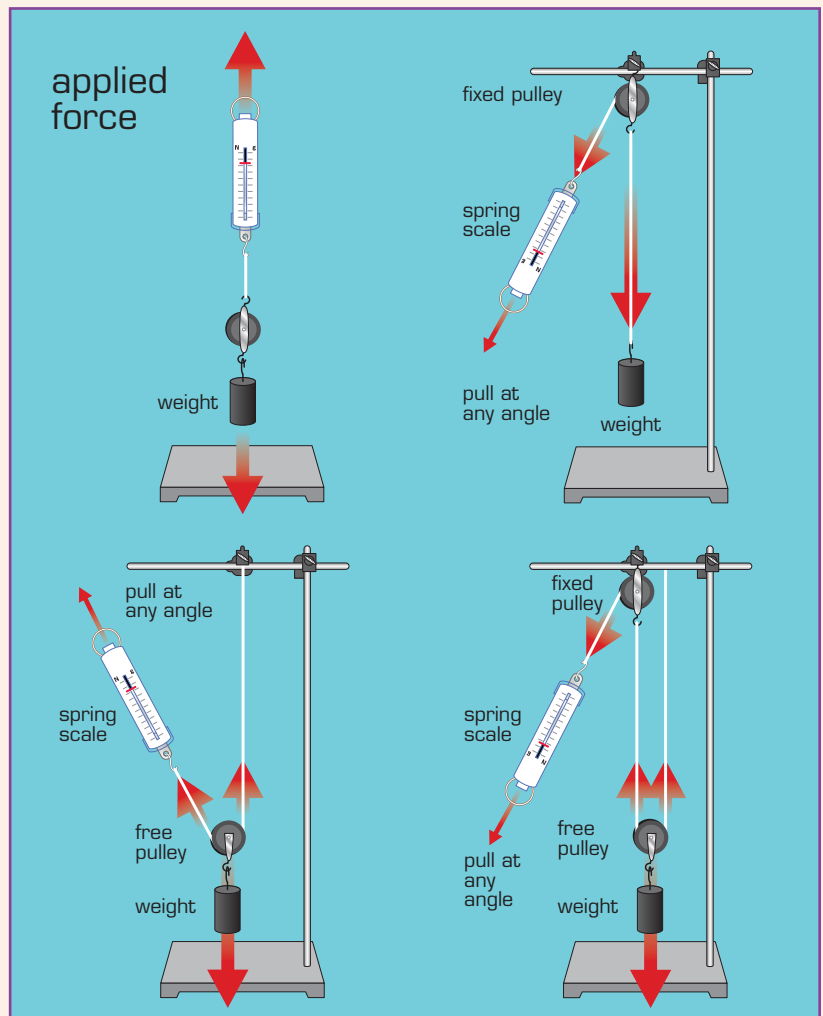
Get Going

Have students meet with their groups to write explanations. Distribute *Create Your Explanation* pages and have groups get started.

□ Assess

Monitor student progress. Ask students what claims they are making and how they are supporting their claims. Expect claims like the following:

- A fixed pulley has a mechanical advantage of one. Our measurements show that the fixed pulley requires the same force as that needed to directly lift the 1-kg mass, and you must apply that force through the same distance as that of the direct lift, but it can change the direction of the applied force.
- A free pulley has a mechanical advantage of two. Our measurements show that the free pulley requires half the force as that needed to directly lift the 1-kg mass, but you must apply that force through twice the distance of the direct lift. It can also change the direction of the applied force.
- For a combination of a free and fixed pulley the mechanical advantage is two. Our measurements show that the combination of a free and fixed pulley requires half the force as that needed to directly lift the 1-kg mass, but you must apply that force through twice the distance of the direct lift. It can also change the direction of the applied force.
- Groups' evidence should come directly from the investigations. Students may use science knowledge about machines, but they do not have much specific science knowledge about levers.
- Help groups as needed with their force diagrams. They should have at least two force diagrams one for the fixed pulley and one for the free pulley. Example force diagrams are provided to the right:



Communicate: Share Your Explanation

10 min.

Have students read their explanations, and create a class explanation.

META NOTES

The claims should come directly from the trends that were just discussed. The evidence should come directly from the investigation. The science knowledge will probably be incomplete. Note any misconceptions and move on. Students will revise their explanations after gaining more science knowledge.



Communicate

Share Your Explanation

When everyone is finished, you will share your explanations with the class. Record the explanations made by other groups. You might also create a poster for the classroom that has the full set of explanations on it. You will have an opportunity to revise your explanations after you learn more about levers.



What's the Point?

Different types of pulleys make moving things easier in different ways. You found that the fixed pulley did not change the amount of force needed to lift the weight. However, it changed the direction in which the force was applied. The moveable pulley reduced the force required, but did not change the direction of the force. When these different types of pulleys are combined into a system, you get the benefits of each type.



Cable and pulley arrangement used alongside railroad tracks.

MBT 86

Project-Based Inquiry Science

△ Guide

When groups have finished creating their explanations, ask each group to share their claims and explanations with the class. Record their claims and explanations on a poster or an overhead slide. Keep this to update later. This allows you to see what students are thinking, and to record their initial claims and explanation so that they can revise them later.

Then discuss whether or not the claims are trustworthy and what it means

for a claim to be trustworthy. Students should recognize that a claim is trustworthy when it has reliable data to support it and when evidence from a number of independent experiments supports the claims. If a claim can be disputed by evidence then it needs to be revised.

Discuss how the force diagrams assist in the explanation and make sure that the force arrows point in the correct direction and have the correct relative length. You may want to do this by selecting two groups with different diagrams and have them draw their diagrams for the class. Then hold a discussion on the diagrams and have the class discuss and correct any features in the diagram.

META NOTES

If students drew their force arrows the wrong ways, you can have students help each other understand the way to draw the arrows. Make sure that the class list has the arrows correct (in the right direction and of the right length relative to each other.)

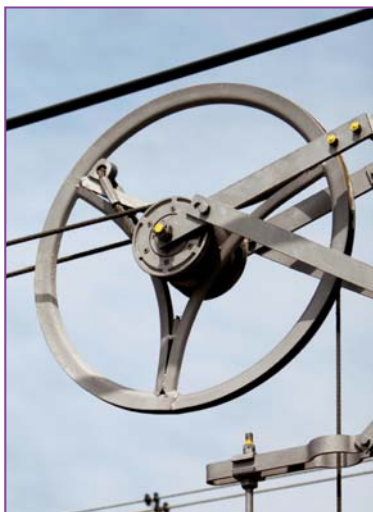
TEACHER TALK

“What are the important features of a force diagram and what do they represent? (Students should recognize that the forces exerted on the object need to be drawn and that the length of the arrow represents the size of the force and that the direction of the arrow represents the direction of the force.)

What features if any need to be added or changed and why?”

**What's the Point?**

Different types of pulleys make moving things easier in different ways. You found that the fixed pulley did not change the amount of force needed to lift the weight. However, it changed the direction in which the force was applied. The moveable pulley reduced the force required, but did not change the direction of the force. When these different types of pulleys are combined into a system, you get the benefits of each type.



Cable and pulley arrangement used alongside railroad tracks.

MBT 86

Project-Based Inquiry Science

What's the Point?

5 min.

Summarize the claims students made in the class and let them know that they will be revising them.

Assessment Options

Targeted Concepts, Skills, and Nature of Science	How do I know if students got it?
<p>Scientists often work together and then share their findings. Sharing findings makes new information available and helps scientists refine their ideas and build on others' ideas. When another person's or group's idea is used, credit needs to be given.</p>	<p>ASK: How did different groups contribute to the class explanation?</p> <p>LISTEN: Students should see that where groups agreed, they reinforced each other, and where they had different ideas, they were able to revise their ideas or they identified where they needed to do more research.</p>
<p>Scientists make claims (conclusions) based on evidence obtained (trends in data) from reliable investigations.</p>	<p>ASK: Where did you get the evidence you used in your explanations?</p> <p>LISTEN: Students should have used the evidence from their investigations.</p>

Teacher Reflection Questions

- How are students progressing in their understanding of mechanical advantage and machines? What troubles did they have drawing force diagrams for pulleys? What ideas do you have for next time?
- What difficulties did students having constructing explanations? What ideas do you have for next time?
- What ideas do you have for monitoring group discussions?