

SECTION 3.2 INTRODUCTION

2 class periods* ►

3.2 Investigate**How Do Levers Change a Force?****Overview**

Students investigate the mechanical advantage of a lever with varying fulcrums. Students are first introduced to the parts of a lever. Then they sketch their predications of how the force and the distance vary as the fulcrum moves closer to the load. By predicting, they become more familiar with the parts of the lever and what variables affect it. Groups then investigate how adjusting the fulcrum of the lever affects the force and distance required to lift a 1-kg mass 10 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 a lever. Students share their analysis and conclusions during an *Investigation Expos*. 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 lever 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' investigations should be fair tests, and they should be able to evaluate each groups' investigation to determine if it is a fair test and describe why or why not.
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.
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 levers realizing that for the lever they investigated, as the fulcrum gets closer to the load the force needed to lift the load a given distance decreases, but the distance the force must be applied increases.
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 lever, and its mechanical advantage.

Materials

1 per group	spring scale (0-20 N)
2 per group	metric ruler
1 per group	1-kg mass
1 per group	lever with eyehooks at the ends
1 per group	ring stand
1 per group	3 inch bolt and wing nut
1 per student	<i>Recording Your Data</i> page
2 per student	<i>Average Force Measurement</i> pages and <i>Average Distance Measurement</i> pages

META NOTES

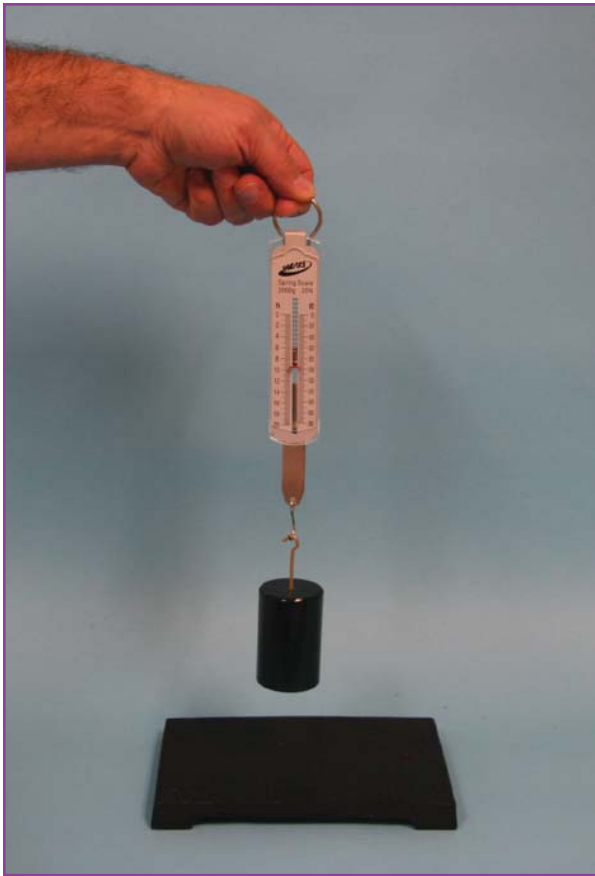
It is important for students to measure and record the distance through which they apply the force, not the distance through which the 1-kg mass is pulled (as indicated in the student edition). The 1-kg mass is pulled a fixed distance of 10 cm for each measurement.

Activity Setup and Preparation

You should have a setup of the equipment to show to the class. You may want to set up the student materials in advance. An image of the setup is shown below.

Run the experiment to determine where your students may have difficulty with setting up the equipment or taking measurements. Students will need two metric rulers, one to measure the height to which the 1-kg mass is pulled to (10 cm) and one to measure the distance that the force is applied through.

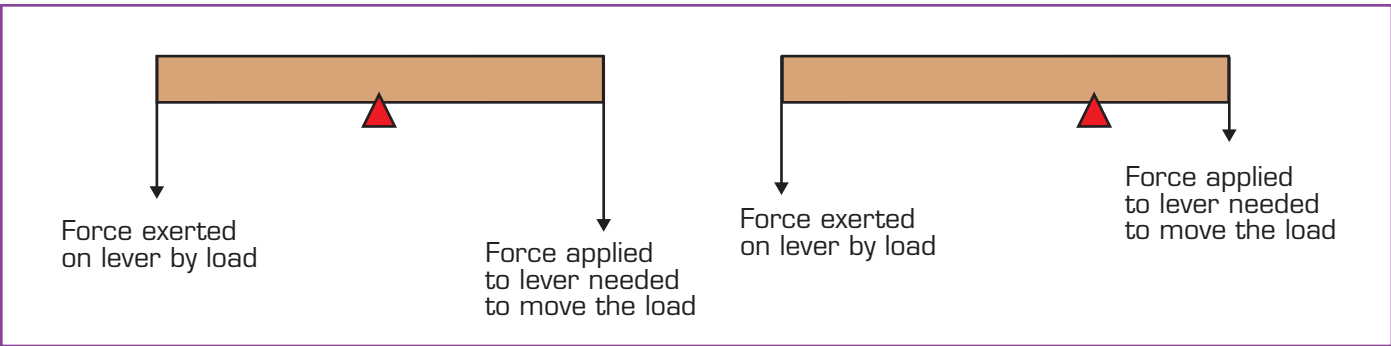
You may want to have students measure the distance the fulcrum is from the load and then construct graphs of the entire set of class data showing how the force needed to move the 1-kg mass varies with the location of the fulcrum, and how the distance the force must be applied for varies with the location of the fulcrum.



Homework Options

Reflection

- **Science Content:** What are some levers that you have used? Name as many as you can. (*Students may list some of the levers mentioned already.*)
- **Science Content:** Draw two force diagrams showing the forces acting on the lever for a fulcrum close to the load and one far from the load. (*Students' drawings should represent forces such that as the fulcrum moves closer to the load, the force required to move the load decreases. The force applied and the load should remain at the same location on the lever. Check the placement of the force arrows, length, and direction.*)
- **Science Process:** What variables did you control during your investigation? How did you control them? (*Students should have controlled the weight of the load they were lifting, the height to which they lifted the load, the way they pulled, and the way they measured. They should have made sure that the weight reached a height of 10 cm for each part of the investigation.*)



- Science Content:** You are prying a can of paint open with a screwdriver. Describe how you are using mechanical advantage. What is the tradeoff? (*The screwdriver decreases the amount of force you have to use to open the lid, but you have to apply the force on the screwdriver a greater distance than you have to move the lid.*)

Preparation for 3.3

- Science Content:** Summarize what you know about how levers change a force. (*Summaries should include a description of the mechanical advantage of levers: The farther the fulcrum is from the pulling force, the less force and the greater distance there is required to lift the weight.*)

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2 class periods ▶

SECTION 3.2 IMPLEMENTATION

3.2 Investigate

How Do Levers Change a Force?

10 min.

Introduce levers.

META NOTES

Transitioning from previous sections helps students to make connections to what they have done and the challenge helps to motivate and focus students on what they still need to learn.

3.2 Investigate

How Do Levers Change a Force?

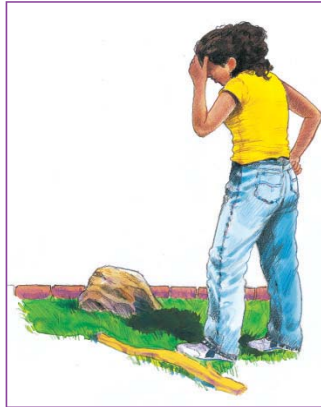
Imagine that you are by yourself and you need to move a big rock. You try lifting and pushing the rock, but it will not move. However, you do see a long stick and a brick. Think about how you could use these to move the rock.

If you have ever used a stick to pry a rock out of a hole, you have used a **lever**. Levers are very basic machines. In their simplest form, they can be a **rigid** bar resting on a **pivot** point. This pivot point is called a **fulcrum**. The object that is being lifted is called the **load**. The push or pull on the lever is called the **force**. You can see each of these on the lever diagram. Just like all machines, levers can make doing work easier.

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

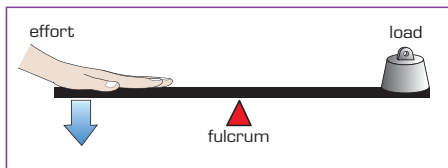
Predict

In the next investigations, you are going to use a lever and see how it changes the force needed to lift an object. A lever is a simple machine. You know that simple machines reduce the force needed to lift something. But the trade-off is that the simple machine adds to the distance you need to lift an object.



rigid: stiff.
lever: a simple machine made up of a rigid bar that pivots around a fixed point (called a fulcrum).
pivot: the point on which something rests and turns.
fulcrum: the point about which the rigid bar of a lever pivots.

History Connection
 Levers, as well as inclined planes, were among the first tools to be used by early humans. The use of levers can be traced back to 5000 B.C.



MBT 69

MOVING BIG THINGS

Engage

Review the challenge again and discuss the questions about levers on the class's *Project Board* and introduce the section.

TEACHER TALK

“We’ve already explored one machine, the inclined plane, but perhaps another machine will make our task easier. There could be a better way of moving the crate up the cliff with a single rope. Look at the questions you have listed as things to investigate on the class’s *Project Board*. Today we are going to consider your questions about levers. You will be investigating the mechanical advantage of levers.”

△ Guide

Then ask students if they are familiar with levers and provide them with a common example such as a seesaw or teeter-totter. Ask students for examples of levers they are familiar with and what they are used for. Record the list of levers and what they are used for.

TEACHER TALK

“Are there any levers you can think of that you use in everyday life? What are some examples? What do you use them for?”

Some possible examples are seesaws, crowbars, mousetraps, shovels, catapults, scissors, and nutcrackers, fork, and shovel.

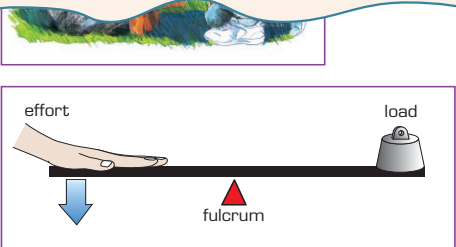
After you have collected a number of ideas, have students try to pick out what is common in these items. Ask students which parts of the lever are important—which parts make it a lever. Then describe a lever using an illustration such as that on page 69 of the text. Go over the introduction with the class, emphasizing the definition of *lever*, *pivot*, and *fulcrum*.

Then let students know they will be investigating how the placement of fulcrum affects the amount of force and the distance the force must be applied for to move a load.

levers help you move a weight.

Predict

In the next investigations, you are going to use a lever and see how it changes the force needed to lift an object. A lever is a simple machine. You know that simple machines reduce the force needed to lift something. But the trade-off is that the simple machine adds to the distance you need to lift an object.



Predict

20 min.

Have students make predictions.

△ Guide

NOTE: The student text says incorrectly on page 70 that students will explore three different levers. The levers for this investigation are all first-class, but the fulcrum is in different positions. Make sure students understand this.

First, use an illustration to describe to students that they will be measuring how much force is needed to lift the 1-kg mass directly, and how much is needed to lift it with a lever. They will be adjusting the lever so that initially the fulcrum is midway between the load and the applied force. Then they

META NOTES

The classes of levers will be discussed in Section 3.5.

will move the fulcrum closer to the load to see how this affects the applied force and how it affects the distance over which they apply the force. Remind them that the load is the 1-kg mass and the applied force is applied on the other side of the lever. Emphasize that the distance the load is lifted will be the same.

Then let students know they will be predicting what will happen to the applied force as the fulcrum position changes, and the distance the force is applied over as the fulcrum changes.

Get Going

Then distribute the *Average Force Measurement* pages and the *Average Distance Measurement* pages, and have students predict how a lever will change the force and distance needed to lift the 1-kg mass to 10 cm.

Assess

Assess students' understanding of what they are to graph while they are working, and consider their predictions. Most students' predictions should show that as the applied force decreases, the distance you apply it for increases.

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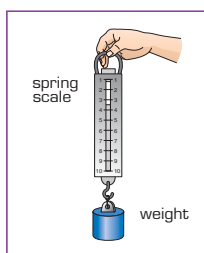
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PBIS

Learning Set 3 • What Other Machines Can Change Force?

Materials

- spring scale (0 N–20 N)
- weight
- ring stand
- bolt (3 in)
- washers
- wing nut
- right-angle clamp
- wooden lever with eyehooks
- string
- scissors
- 2 1-m rulers



On a graph like those you used in the last *Learning Set*, sketch your prediction about what you think is going to happen when you lift the weight using a lever. You will explore use of three different levers. The fulcrum on each will be in a different place, starting at the center of the lever and moving closer to the load.

Procedure

In this investigation, you are going to use a lever to lift a weight. First, you will lift the weight straight up. Then you will lift it to the same height using various levers. The first lever will have the fulcrum located at the center of the board. For the next parts of the investigation, you will move the fulcrum closer to the load. You will compare the force applied and the distance moved.

Part 1: Lifting the Weight without a Lever

In this part of the investigation, you will be lifting the weight 10 cm from the top of the table. Use the ruler to measure the height accurately. Use the spring scale to measure how much force you had to use to lift the weight off the table.

1. Use the diagram to help you set up your equipment correctly.
2. Attach the spring scale to the weight. Lift the weight 10 cm above the table using the spring scale. Measure the 10 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 10 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.

You have now lifted the weight to see how much force you need to lift the weight straight up from the table. This weight was not too heavy to lift. Some weights, like the crate on the beach, are very heavy. Use the next part of this procedure to see how a lever can help move the weight.

Part 2: Using a Lever to Lift the Weight

In this part of the investigation, you will be using a lever with the fulcrum in three different places to lift the weight 10 cm. The height you will lift the weight will stay constant so you will be able to compare your force data to the force data for just lifting the weight straight off the table. You will need to measure the distance you pulled to get the weight 10 cm from the table.

Project-Based Inquiry Science

MBT 70

Procedure

20 min.

Guide students through running the procedure and collecting data.

△ Guide

Begin by discussing the procedure with the class and showing them the equipment.

Let students know that each group will be running a two-part investigation. In the first part they will measure the force needed to lift the 1-kg mass without a lever. In the second part students will lift the mass with the lever. Show students the apparatus and point out how they will create the fulcrum, where they will place the load (the 1-kg mass), and where

META NOTES

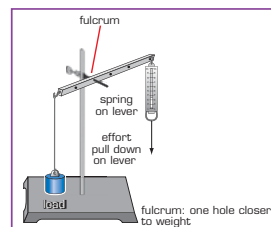
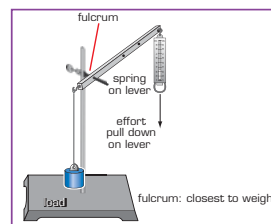
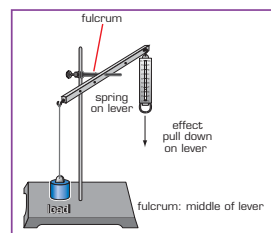
The first part of the experiment is identical to when they lifted the mass directly in the inclined plane experiment.

META NOTES

You may want to have students measure the distance the fulcrum is from the load and later construct graphs of the entire set of class data showing how the force needed to move the 1-kg mass varies with the location of the fulcrum, and how the distance the force must be applied for varies with the location of the fulcrum.

3.2 Investigate

1. Use the diagram to help you set up your equipment correctly. Notice the parts that are identified: fulcrum, effort, and load. The lever should be in the horizontal position and the fulcrum is at the center. Put the meter stick next to the lever and measure 10 cm up from the table. Hold the ruler at this position.
2. Attach the spring scale to the lever at one end. Hang the weight from the other end of the lever.
3. Put the other meter stick next to your hand. Be ready to measure how far you have to pull down on the lever.
4. Pull down on the spring scale until the weight is 10 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 weight. Record that measurement on your data table.
6. Use the ruler to measure how far down your hand moved to pull the weight up 10 cm. On the data table, record the distance your hand moved.
7. Repeat this procedure in the same way two more times for a total of three trials. Record all the data on your data table.
8. Move the fulcrum of the lever toward the load. Set it in the next hole. Repeat Steps 2 through 7 of the procedure.
9. Move the fulcrum one more hole closer to the load. Again, repeat Steps 2 through 7.



Recording Your Data

Use the following tables to record your data from each trial.

Vertical Lift		Fulcrum at Center		Fulcrum Closer to Load		Fulcrum Closer to Load	
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)	force to pull weight (N)	distance weight is pulled (cm)

MBT 71

MOVING BIG THINGS

their applied force will be. Show them how they will measure the distance they move the 1-kg mass (fixed at 10 cm) and how they will measure the distance they apply the force through. Then show them how to read the spring scale. They should measure the spring scale as they are moving the mass downward with a constant speed.

NOTE: In Part 2, on page 71, the diagrams on the right are out of order. Have students mark the top image as 1, the middle image as 3, and the bottom image as 2, and do their investigation in that order. Also, note that the lever in the middle image is missing a hole. There should be three

holes between the fulcrum and the spring scale in the third setup. Then 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 edition). The 1-kg mass is pulled a fixed distance of 10 cm for each measurement.

At this point, you could get into a discussion about fair tests and ask why the 1-kg mass should be pulled a fixed distance.

Remind students that they should monitor the data as it is collected to assure proper data collection methods in the investigation.

Get Going

Distribute the materials, give groups a time frame, and get them started.

Guide and Assess

Monitor student progress. Check to see if all groups are following the procedures and recording their data. The location of the fulcrum does not need to be the same for all groups. Groups will only be comparing trends in their data, not the actual data. If any groups are coming up with results that are very different from what is expected, ask them to show you how they got the results and help them figure out what they're doing wrong. If appropriate, discuss outliers with students. Students' data should show the trend that the applied force decreases as the fulcrum moves closer to the load and the distance the force is applied for increases. The amount of force needed when the fulcrum is located in the center should be approximately equal to the amount of force needed to directly lift the 1-kg mass 10 cm.

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Analyze Your Data

15 min.

Have students graph and analyze their data.

Vertical lift		Fulcrum at center		Fulcrum closer to load		Fulcrum closest to load	
Average force to lift weight (N)	Average distance weight is lifted (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)

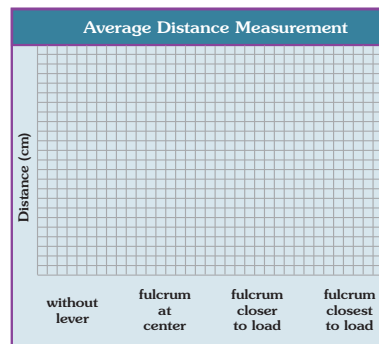
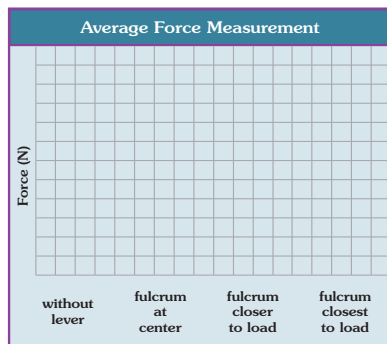
Analyze Your Data

You should now have data from lifting the weight straight from the table and then lifting the block the same height, 10 cm, with three different levers. You will now analyze your data to see how the levers made a difference in how much force was required to lift the block.

Force

You took three force measurements for each part of the investigation. Average these measurements to find the average force needed for each part. You should have four data points when you are finished.

Create a bar chart using these average measurements. Bar one should be the lift straight off the table, bar two is the horizontal lever, and so on. Make sure you have four bars on your chart when you are finished.



MBT 72

Project-Based Inquiry Science

△ Guide

Students should find the averages of their data and graph the averages on the *Average Force Measurement* and *Average Distance Measurement* bar charts. Each student should do this and then the group should discuss their results and answer the questions in the student text.

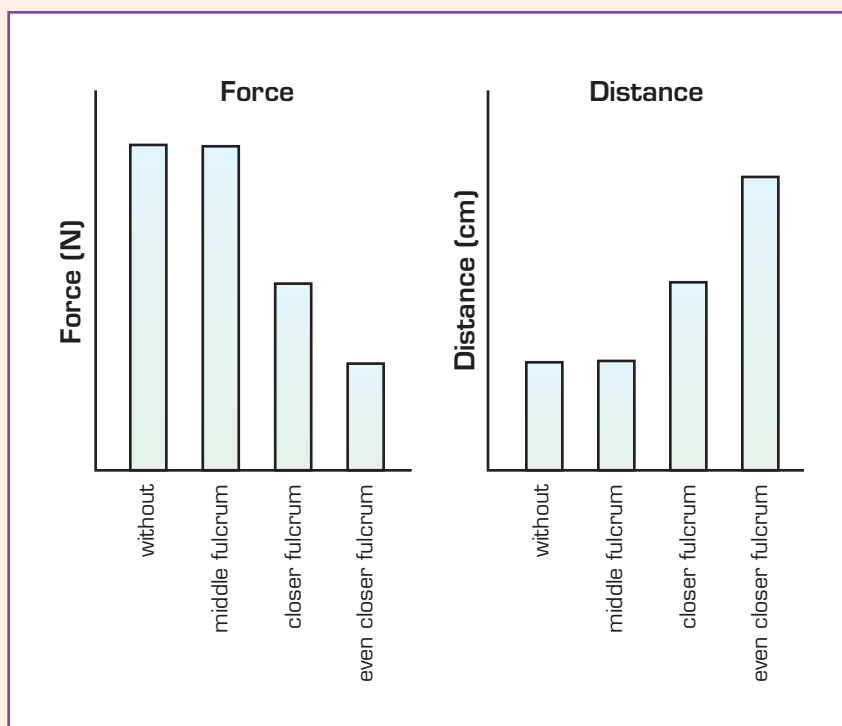
TEACHER TALK

“You should analyze your data as you did for the inclined plane. First find the averages and then make bar charts of these averages. You should have two bar charts, one for the average force as the fulcrum position changes, and one for the average distance as the fulcrum position changes. After you each do this, discuss your results as a group and answer the questions about your data.”

◆ Evaluate and Assess

Make sure students are calculating their averages correctly. Also, make sure that they have four bars on each of their bar charts when they're done.

Assess students' graphs. They should look similar to the ones below.



Once students have finished their bar charts, they should answer as a group the three questions. There is no need for a class discussion of their responses. They will use these responses to help them find trends, understand mechanical advantage, and make claims about their investigations. These will be presented and discussed during the *Investigation Expo*.

Communicate Your Results:

Investigation Expo

20 min.

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

META NOTES

Note that all groups will be viewing the posters, but only two groups will present their results. As groups are preparing, determine which groups you want to present. The discussion following presentations will focus on discussing mechanical advantage.

META NOTES

Also, determine if you want to construct a class graph of all the average data points to show the class trend. If you do this, it is very important that everyone is following the same procedure and only varying the fulcrum position of the lever.

3.2 Investigate

Distance

You took three distance measurements for each part of the investigation. The distance is how far you had to move your hand to pull the weight off the table 10 cm. Average the distance for each part. You should have four data points when you are finished.

Create another bar chart using these average measurements. Bar one should be the lift straight off the table, bar two is the horizontal lever, and so on. Make sure you have four data points on your graph when you are finished.

The two bar charts you have created give you a lot of information about the relationship between force and distance when you use a lever to help you lift something. Answer the following questions to help you better understand the charts.

1. The force bar chart shows the trend in the data for force. As you moved the fulcrum toward the load, what happened to the amount of force needed to lift the weight 10 cm off the table? Start your claim with, "As the fulcrum is moved toward the load," Use evidence and science knowledge to support your claim.
2. The distance bar chart shows the trend in the data for distance. As you move the fulcrum toward the load, what happens to the distance you move your hand in order to lift the weight 10 cm off the table? Start your claim with, "As the fulcrum is moved toward the load, ..." Use evidence and science knowledge to support your claim.
3. The two bar charts work together to help you better understand another aspect of machines. Observe the trends on both charts. Explain the relationship between force and distance from these charts. Start your claim with "As the fulcrum moves toward the load, the force ... and the distance ..." Make sure to include both force and distance in your sentence. Use evidence and science knowledge to support your claim.

Communicate Your Results

Investigation Expo

Scientists always share their understandings with each other. Presenting their results is one of the most important things scientists do. You will share what you have found in an *Investigation Expo*. To prepare for this, you will make a poster that answers the following questions:

- What question were you trying to answer in the investigation?



MBT 73

MOVING BIG THINGS

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 73 and 74. Emphasize that they will need to determine 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.



Learning Set 3 • What Other Machines Can Change Force?

- 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?



The handle of this old-fashioned water pump is an example of a first-class lever.

Remember, it is important to report the procedure you used in your investigation. Each group may run their investigations differently. It will be important to compare results from these different tests. If you think the test you ran was not as fair as you had planned, you might want to report on how you would change your procedure if you had the chance to run the investigation again.

Because everyone did the same investigation, during this *Investigation Expo* you will put your posters on the wall. When all the posters are displayed, you and your classmates can walk around and look at each one.

As you look at the other posters, examine them closely to see if you can answer this set of questions for each one.

- 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 required to lift the weight in a consistent way each time the fulcrum was moved?
- Did their procedure cause them to run a poor, uncontrolled experiment?
- What did they learn?
- What conclusions do their results suggest?
- Are their results the same as yours?
If not, why not?

After looking at the posters, your class will discuss the answers to these questions and what you learned from your investigations about levers and how they help lift heavy things.

MBT 74

Project-Based Inquiry Science

Once all groups have finished their posters, have each group put their poster up on the wall, and have two groups present their results to the class. Have groups review each other's posters and have a class discussion.

△ Guide

When groups have completed their posters, have them display their posters around the room. Then inform the class that when they visit each other's posters they will need to examine the posters closely to make sure they can answer the bulleted questions on pages 73 and 74. Emphasize that they

META NOTES

Make sure students save their graphs. They will be revisiting them throughout the Unit. They will need them for Section 2.4, where tradeoff and mechanical advantage are defined.

META NOTES

The concept of *work* will be discussed after students have read more about distance-force tradeoffs in Section 2.4. Save discussion of work for then.

should take notes to prepare for a class discussion. Then let each group visit each poster for a minute or two.

After groups have reviewed the posters have the two groups you selected present their results. Then focus the discussion on the three questions.

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 as the fulcrum moved closer to the load, the force needed to lift the 1-kg mass to 10 cm decreased. As the amount of applied force students needed to lift the weight decreased, the distance they needed to apply that force increased.

If you decided to construct a class graph of the data, this would be a good time to and then lead into a discussion of the trends in the data.

Discuss how their data of the lever compares with that of the inclined plane.

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3.2 Investigate

Reflect

As you answer the following questions, reflect on the lever investigations you just completed. Also, think about how the lever is similar to the inclined plane. Be prepared to share your answers with the class.

1. What happened to the amount of force needed to lift the weight as the fulcrum was moved closer to the weight?
2. What happened to the distance you had to move the lever down as the fulcrum was moved closer to the weight?
3. In the last section, you learned about mechanical advantage. All machines have some mechanical advantage. Describe the mechanical advantage of the levers you investigated.

What's the Point?

In this section, you investigated levers and how the position of the fulcrum affects the amount of force needed to lift a weight. You also compared distances through which the force was applied in each situation. The bar charts helped you understand the relationship between force and distance for the levers. They showed that the amount of force needed to lift the weight decreased as the fulcrum moved closer to the load. The trade-off of force and distance is common to all simple machines. When the fulcrum is moved closer to the load, less force is needed to move the block but you have to move the lever a greater distance.



In an oil pump, a lever is used to create a suction that draws oil up from the ground.

MBT 75

MOVING BIG THINGS

Reflect

5 min.

Have students answer the Reflect questions as a quiz or for homework.

What's the Point?

5 min.

Summarize mechanical advantage and its relationship to the machines so far investigated.

△ Guide

You can use the *Reflect* questions as a quiz or you can assign them for homework. You've discussed this content with the class before—the purpose of these questions is to help students learn to articulate these concepts—so there is no need to discuss them in class.

Assessment Options

Targeted Concepts, Skills, and Nature of Science	How do I know if students got it?
<p>Graphs are an effective way to communicate results of scientific investigation.</p>	<p>ASK: How were you able to find the trends in your data?</p> <p>LISTEN: Students should recognize that their graphs helped them to see the trends in their data.</p>
<p>Mechanical advantage is the tradeoff between force and distance.</p>	<p>ASK: What was the mechanical advantage when you used levers to lift the weight?</p> <p>LISTEN: Students should see that the tradeoff was between the force they had to use to lift the weight and the distance they had to pull.</p>

Teacher Reflection Questions

- How are you connecting mechanical advantage in levers to mechanical advantage in inclined planes? How can you connect mechanical advantage in different machines?
- What do you think students get out of the *Investigation Expos*? How can you tell?
- How could you tell students were engaged when they viewed the posters during the *Investigation Expos*? What ideas do you have for next time?