SECTION 3.5 INTRODUCTION

3.5 Read

How Do a Pulley, a Lever, and a Wheel and Axle Change Force?

◀ *1 class period**

Overview

Students read about the three classes of levers, the pulley, and the wheel and axle. They are provided with many examples of the three classes of levers and discuss the mechanical advantage of levers. Then they review pulleys and are introduced to the wheel and axle and discuss the mechanical advantage of this machine. They then describe, identify, and explain how these machines are used in various situations.

Targeted Concepts, Skills, and Nature of Science	Performance Expectations
Machines provide mechanical advantage to assist in moving objects. Mechanical advantage is the tradeoff between force and distance.	Students should be able to describe the tradeoff in levers, pulleys, and the wheel and axle system.
There are six different simple machines all of which provide mechanical advantage: Inclined plane, wedge, screw, wheel and axle, lever, and pulley.	Students are able to describe how mechanical advantage makes moving objects easier using descriptions of levers, pulleys, and the wheel and axle.
There are three different types of levers in which the load, effort, and fulcrum are in different places in relation to each other.	Students should be able to describe and identify the three different classes of levers.

Materials

1 per classroom	lever (board and fulcrum) to demonstrate three classes
1 per classroom	pulley examples
1 per classroom	wheel and axle examples
1 per classroom	projection of *The Lever* from page 88

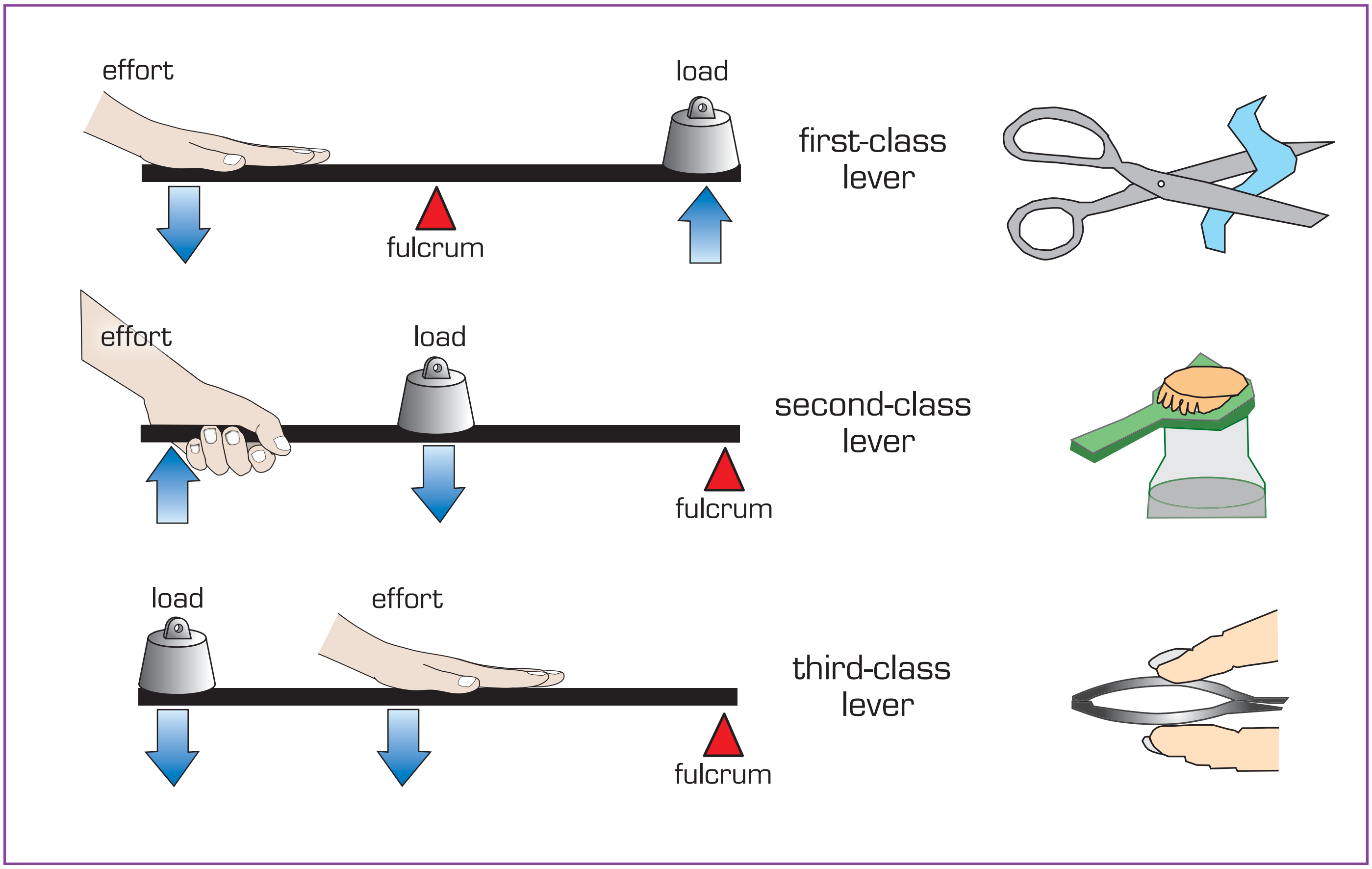
*A class period is considered to be one 40 to 50 minute class.

Activity Setup and Preparation

Look for materials to demonstrate the three machines. Consider using the kit equipment or just a ruler, a small block, and some type of load and set up the three classes of levers as shown below. The images in the student text on page 88 are not completely correct. Having a physical model for them to see as well as a projection of the correct images should increase student understanding.

Decide how you want to proceed with the discussion on pulleys. Much of it is review and students have just completed the investigation of pulleys. You can use the same examples from the previous section of where pulleys are used: Window blinds, drapes, and flagpoles.

For examples of the wheel and axle, consider a screwdriver, door knob, gears, Ferris wheel, wind mill, etc.



Homework Options

Reflection

- **Science Content:** List an example for each class of lever different from those in the student text, and describe how it is used and the mechanical advantage of it. *(Students should describe where the fulcrum, load, and effort are placed and how they affect the force and distance the force is applied through.)*
- **Science Content:** List an example of where you have seen a pulley system used and where you have seen a wheel and axle used. *(Students should be able to identify simple machines in everyday items.)*

Preparation for 3.6

- **Science Process:** Construct explanations about how the simple machines you have learned about relate to force. *(Students will construct explanations for the lever and pulley during the next section.)*

NOTES

NOTES

3.5

SECTION 3.5 IMPLEMENTATION

3.5 Read

How Do a Pulley, a Lever, and a Wheel and Axle Change Force?

You just investigated two more simple machines, the lever and the pulley. In the investigations, you were able to see that simple machines can do two things. They can change the direction of the force or they can multiply the force. In this section, you will learn more about the lever and pulley. You will also read about one other type of simple machine, the wheel and axle.

In a seesaw, the fulcrum is halfway between the load and the effort.

The Lever

You may have played on a seesaw (teeter-totter) at the playground. A seesaw is so much fun because your friend's weight pushing down lifts you up. A seesaw is an example of a lever. A seesaw can be used to lift heavy objects. In the investigation, you use a lever to lift a weight.

All levers have some type of pivot point called a fulcrum. The lever rotates, or turns, around the fulcrum. The position of the fulcrum when compared to where the force, or effort, is applied, determines how the lever can be used. The applied force is called the **effort**. The weight being moved is called the **load**. Differences in the position of the fulcrum, the effort, and the load result in three different classes of levers.

Scissors, boat oars, and crowbars are all similar levers. When you push on one end of the lever, the other end of the lever pushes up. These are all **first-class levers** because the fulcrum is between the effort and the load. First class levers can change the direction of the effort.

effort: the applied force.

load: the weight being moved or the resisting force.

first-class lever: a lever in which the fulcrum is positioned between the effort (applied force) and the load (weight being moved).

◀ *1 class period*

3.5 Read

How Do a Pulley, a Lever, and a Wheel and Axle Change Force?

35 min.

Introduce the reading of levers, pulleys, and the wheel and axle.

META NOTES

Eliciting students' initial ideas is a good way to inform you of what you may need to focus on when teaching new material, and it assists in students constructing and refining ideas.

◯ Engage

Begin the section by having students make connections with what they have learned so far and the different types of levers. Show students a simple lever (a ruler and a small block) and ask them all the ways they could arrange the fulcrum, load, and effort.

Record students' ideas, drawing images of how they think the lever is constructed.

TEACHER TALK

"We are going to learn more about levers, pulleys, and the wheel and axle. Before we read about levers I'd like you to think about them. Here are some parts of a lever (the bar or beam and the fulcrum). The other ingredients of a lever are the load (what you are moving) and the effort (the force you are applying). What are the ways I can arrange the load, effort, and fulcrum and what affects do you think they will have?"

The Lever

15 min.

Discuss the three classes of levers.

META NOTES

It is important for students to have physical models as well as visual models. If you brought in examples of the three types of levers you may want to pass them around the room after you discuss each class of lever.

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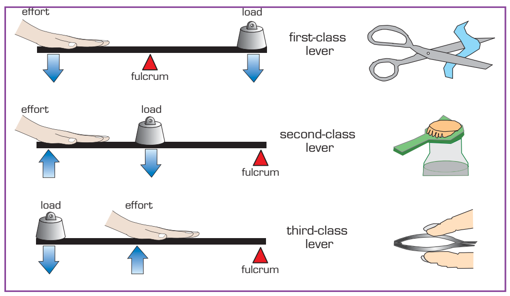
MOVING BIG THINGS

△ Guide

Introduce the three classes of levers. Project the correct image of the three classes of levers and note that the image in the student text on page 88 of the three classes of levers is incorrect. Then show students how each one of the levers physically looks by constructing it with the lever materials you used at the start of class. Point out whether or not students described all the classes of levers from the list created earlier.

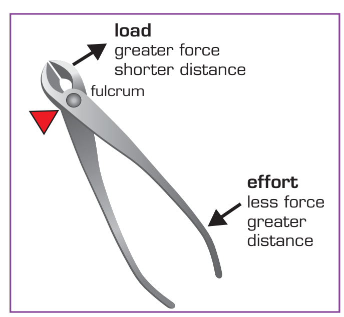
Next, begin a class discussion of first-class levers. Describe how they can multiply the applied force so that the applied force can be larger or smaller than the force acting on the load. This can be done by varying the position the applied force (the effort) and the load are placed around the fulcrum.

Scissors are made up of two first-class levers connected by a pivot point. The pivot point acts as a fulcrum. When you push down on the top handle of a pair of scissors, that blade moves up. As you lift up on the bottom handle of the scissors, that blade moves down.



First-class levers can also multiply the applied force. If the fulcrum of a first-class lever is moved closer to the weight being moved (the load) the amount of force (effort) needed to move the load is less. However, the effort end of the lever, where the force is being applied, must move a greater distance than the load.

For example, branch cutters are designed to cut through much thicker, tougher materials than scissors. Look at the pictures of the scissors and branch cutters. Notice the difference between them. The fulcrum (pivot point) is closer to the load end in the branch cutters. The load end, or blades, of the branch cutters is much shorter than the effort end, or the handles. The blades move a smaller distance than the handles. This is because the force, or effort, is being applied through a longer distance. The tradeoff is that it takes less force to cut through thick branches, but you must apply the force over a greater distance.



META NOTES

You could demonstrate this with the materials from the kit. Place the fulcrum of the lever in the middle and balance two 1-kg masses on one side and a 1-kg mass on the other.

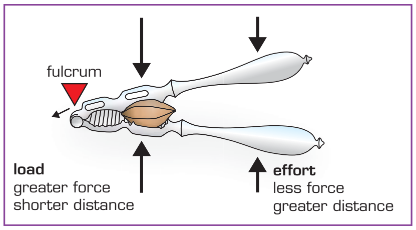
Give examples of a seesaw with a child and an adult sitting on it. For the child to be able to work the seesaw with the adult, the adult will need to sit closer to the fulcrum. When the child supplies the effort force than that force is increased to move the load (the adult), when the adult supplies the effort, their applied force is reduced to safely move the child. Point out also that the adult moves a different distance than the child.

In **second-class levers**, the load is positioned between the fulcrum and the applied force, or effort. Second-class levers do not change the direction of the force. However, they do multiply the applied force. A bottle opener is a good example. As you lift on the end of the bottle opener, it lifts the cap off the bottle. A nutcracker is another example of a second-class lever. You apply a force at the end of the handles to crack a nut between them.

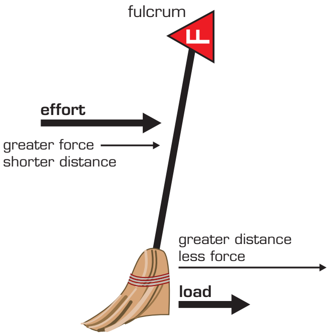
second-class lever: a lever in which the load is positioned between the fulcrum and the applied force.

third-class lever: a lever in which the effort is positioned between the fulcrum and the load.

Third-class levers have the fulcrum positioned at one end and the load at the other end. The force is applied in the middle. Like second-class levers, third-class levers do not change the direction of the force. Third-class levers multiply the distance of the applied force. This means that the force you apply must always be greater than the force of the load.



Tweezers are a good example of a third-class lever. You squeeze the tweezers in the middle and they exerta force at the end. A broom is another example of a third-class lever. The fulcrum is at the top of the broom, you apply a force in the middle, and the broom moves dirt at the bottom. In both examples, the amount of force you apply is greater than the force needed to do the task. However, the distance you must apply the force is much less. It is easier in these cases to apply more force through a short distance than to apply less force through a long distance.



Then describe the examples of first-class levers provided in the text: Scissors (levers and wedges combined), branch cutters or pruning sheers (levers and wedges combined), and the wrench. Emphasize how these levers increase the applied force and decrease the distance the load moves through. Also, point out that this type of lever changes the direction of the force.

TEACHER TALK

"For all these examples of first-class levers we see that if the first-class lever increases the applied force, then the distance it moves the load is shorter than the distance it moves the applied force."

Then discuss second-class levers in which the load is between the fulcrum and the effort. Show students the image and a physical model of the lever. Ask students if they know of any examples. Then describe the examples in the student text of the bottle opener and the nutcracker. Emphasize that the second-class lever increases the amount of force acting on the load, but the distance it acts on the load is less than the distance the applied force is provided, and does not change the direction of force. If you brought in examples of second-class levers, discuss them with the students.

Next, introduce third-class levers to the class. Point out on the projection that it looks very much like the second-class lever, but this time the effort rather than the load is located in the middle—between the fulcrum and the load. Describe how the force can be decreased and the distance increased as is the case for the rake, and the example of the tweezers where the force is increased and the distance decreased.

Then emphasize the mechanical advantage can be greater than or less than one, depending on whether or not it is increasing or decreasing the applied force. (If it decreases the applied force, it is less than one as is the case for a rake.)

NOTES

Pulley

5 min.

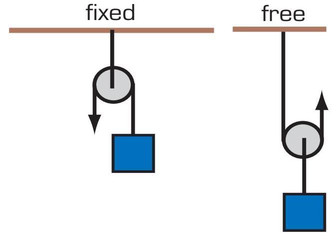
Guide students through the reading of pulleys.

META NOTES

Since students have just completed the investigation of pulleys and there is not much new here, you may go through this reading quickly.

The Pulley

The pulley is another type of simple machine. As you saw in your investigation, there are two types of pulleys—the fixed pulley and the free pulley. Fixed pulleys are attached to a fixed support, like a wall or ceiling. A fixed pulley changes the direction of the applied force. For example, it can change a pulling force into a lifting force. Fixed pulleys do not reduce the amount of force you need to apply.



A free pulley is attached to the load. The pulley moves along with the load when the string is pulled. A free pulley reduces the amount of force needed to move the weight, but does not change the direction of the force.

Fixed pulleys and free pulleys can be combined to make a pulley system. You then get the benefit of each type. In a pulley system, you must pull on more rope than if you were just lifting the load. The system, however, changes the pulling force to a lifting force and reduces the amount of force needed to lift the load. You may have seen a pulley being used on a sailboat to lift the sails or on a weightlifting machine at the gym.

The Wheel and Axle

wheel and axle: a simple machine made up of a wheel (a circular object) that turns around an axle (a circular object that is smaller than the wheel).

The final type of simple machine is the **wheel and axle**. The wheel and axle changes a small force into a larger force. The small force is applied in a turning direction to the wheel. This changed into a larger turning force, applied at the center of the wheel (axle). An example of a wheel and axle is a steering wheel in a car. The force that a driver applies to the outside edge of the steering wheel is much smaller than the force needed to turn the axle, which turns the car wheels. However, the edge of the steering wheel must move through a much longer distance than the axle. It has to move the whole distance around the outside of the steering wheel

△ Guide

Review the two types of pulleys and ask students to describe them and the mechanical advantage. Then describe how the fixed pulley is fixed to a wall or ceiling and how it can only change the direction of the applied force, not the amount. Then describe the free pulley and how it doubles the applied force and changes the direction. Note the examples in the student edition and ask students if they have any other examples.

Consider drawing the force diagrams for the pulleys.

The Wheel and Axle

15 min.

Introduce students to the wheel and axle.

…eeded to lift the load. Yo… …ve seen a pulley u… …sailboat to lift the sails or on a weightlifting machine at the gym.

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△ Guide

Describe the wheel and axle to the students. The wheel and axle can multiply a force. Gears are a good example of this or the steering wheel of a car. A small force can be applied to the outer rim over a large distance and a large force then acts on the axle to rotate it over a small distance.

Describe the examples provided in the student text and show some example to the class such as a screwdriver, a gear box, and a door knob.

NOTES

Stop and Think

10 min.

Have students answer the Stop and Think *questions and guide a class discussion.*

META NOTES

Consider having the examples of simple machines available for students to look at and explore while they work on the *Stop and Think* questions.

Like other kinds of simple machines, a wheel and axle system makes it easier to do work. Also like other machines, there is a tradeoff between the amount of force you apply and the distance over which you must apply that force. Machines cannot change the amount of work that is done. They can only change the force that is required.

Stop and Think

1. Levers are used to lift very heavy things. The head of a claw hammer is one type of lever. Look at this picture of a claw hammer removing a nail. Identify the effort, load, and fulcrum of this lever. Identify the class of lever.

2. A mechanic's garage might have a pulley hanging from the ceiling. It might be used to lift an engine out of a car. Sketch a picture of how the pulley system might work.
3. A combination of pulleys has some advantages over using only one type of pulley. Explain one advantage of using combinations of pulleys.

△ Guide

After exploring the lever, pulley, and wheel and axle, transition students by asking them if they can think of any other examples of simple machines. Lead a discussion of what they observed and what they read.

What other examples can you think of for the lever, pulley, and/or wheel and axle? How are they used?

△ Guide and Assess

Let students know they will be applying what they know to identify, describe, and explain various simple machines. Have students write their answers to the *Stop and Think* questions and discuss them as a group. Then lead a class discussion of their best group responses.

1. The claw hammer removing a nail is a third-class lever. The fulcrum is at the blunt end of the hammer, the effort is located in the middle, and the load is at the claw removing the nail.
2. Students should have a sketch of a fixed pulley on a ceiling lifting a load. On one side of the pulley should be the load attached to the rope or cable. Students may indicate a force arrow showing the force applied to the load as upward. On the other side students may indicate someone pulley on the rope or cable. Students may draw the applied force downward (along direction of rope) and of the same size as that acting on the load.
3. Students should realize that a combination of pulleys allows you to reduced the applied force needed to lift a load and change the direction of the force. For example, each free pulley used reduced the force needed by two, and each fixed pulley assists in changing the direction. It should be noted that the free pulley can change the direction as well, but not greater than 90˚ from the original direction. The fixed pulley can change the direction by 180˚.

At this point it would be useful to update the *Project Board.*

Targeted Concepts, Skills, and Nature of Science	How do I know if students got it?
Machines provide mechanical advantage to assist in moving objects. Mechanical advantage is the tradeoff between force and distance.	**ASK:** How do simple machines and their mechanical advantage help us? **LISTEN:** Students should be able to describe mechanical advantage and how there is always a tradeoff between force and distance for simple machines with a mechanical advantage different from one.
There are six different simple machines all of which provide mechanical advantage: Inclined plane, wedge, screw, wheel and axle, lever, and pulley.	**ASK:** Describe the mechanical advantage of each of the six simple machines. **LISTEN:** Students should be able to describe the force/distance tradeoffs for each of the simple machines.

META NOTES

Some students may suggest combining a number of free pulleys together. Each free pulley will reduce the amount of force needed by ½. For example two free pulleys will reduce the force by ½ of ½ or to ¼ of what is needed. Three free pulleys will reduce the force needed by ½ of a ½ of a ½ or ⅛ of what would be needed to directly lift the load.

META NOTES

The *Project Board* can be updated at any time. Lead a discussion updating the class's *Project Board* whenever you feel your students have learned a sufficient amount of material.

Targeted Concepts, Skills, and Nature of Science	How do I know if students got it?
There are three different types of levers in which the load, effort, and fulcrum are in different places in relation to each other.	**ASK:** Describe and identify the three different classes of levers. **LISTEN:** Students should be able to describe the three different types of levers in terms of where their fulcrum, effort, and load are located and provide examples or identify from a list of examples what each lever type is.

Assessment Options

Teacher Reflection Questions

- What difficulties did students have understanding the three classes of levers? What evidence do you have that students understand the mechanical advantage of machines?
- What evidence do you have that students are comfortable constructing explanations? What ideas do you have for assisting students that have difficulty in constructing explanations?

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