## LEARNING SET 3 INTRODUCTION

# Learning Set 3

# What Other Machines Can Change Force?

◀ *8 class periods**

*Investigating how levers and pulleys help lift a weight, students observe a tradeoff between the force required to lift something, and the distance it has to be moved.*

## Overview

Students investigate levers and pulleys, and read about the wheel and axle. They begin by considering the importance of mechanical advantage and machines for moving things. Then they come up with questions about different machines and what they need to learn to complete the challenge. Next, students investigate levers and pulleys using the same data gathering procedures as in *Learning Set 2*. Again, students develop a qualitative idea about the tradeoffs of machines referred to as *mechanical advantage*. After each investigation, students share their results in an *Investigation Expo*. They then use the information from all students' investigations to support developing an explanation of how the simple machine can change force. Various classes of levers and uses of pulleys are introduced in a reading. The variations of machines are developed so students might be able to use different configurations in their final machine. After the reading, students revise their explanation, using the additional evidence to support their revision. Finally, students revise the design plan for the challenge that they began in *Learning Set 2*, ideally incorporating levers and/or pulleys in the design. They conclude by sharing their plans with the class and updating the *Project Board*.

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

| Targeted Concepts, Skills, and Nature of Science | Section |
|---|---|
| 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. | 3.1, 3.2, 3.3, 3.4, 3.6, BBQ |
| Criteria and constraints are important in design. | BBQ |

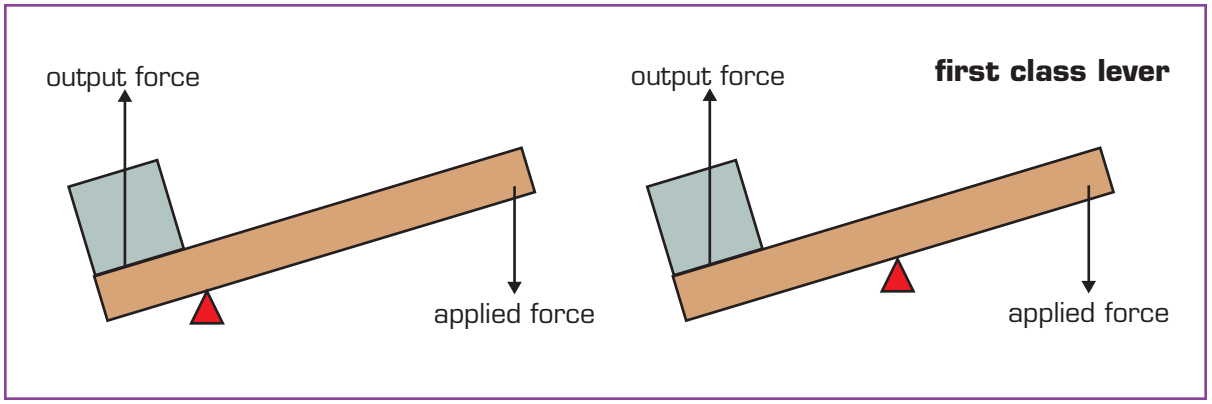
| Targeted Concepts, Skills, and Nature of Science | Section |
|---|---|
| Scientists must keep clear, accurate, and descriptive records of what they do so they can share their work with others and consider what they did, why they did it, and what they want to do next. | 3.1, 3.2, 3.3, 3.4, 3.6, BBQ |
| Graphs and tables are an effective way to communicate results of scientific investigation. | 3.2, 3.4 |
| Scientific investigations and measurements are considered reliable if the results are repeatable by other scientists using the same procedures. | 3.2, 3.4 |
| In a fair test only the manipulated (independent) variable, and the responding (dependent) variable change. All other variables are held constant. | 3.2, 3.4 |
| Scientists make claims (conclusions) based on evidence obtained (trends in data) from reliable investigations. | 3.2, 3.3, 3.4, 3.6 |
| Explanations are claims supported by evidence, accepted ideas, and facts. | 3.3, 3.4, 3.6 |
| Scientists use models to simulate processes that happen too fast, too slow, on a scale that cannot be observed directly (either too small or too large), or that are too dangerous. | BBQ |
| Machines provide mechanical advantage to assist in moving objects. Mechanical advantage is the tradeoff between force and distance. | 3.1, 3.2, 3.3, 3.4, 3.5 |
| There are six different simple machines, all of which provide mechanical advantage: Inclined plane, wedge, screw, wheel and axle, lever, and pulley. | 3.2, 3.3, 3.4, 3.5, 3.6, BBQ |
| There are three different types of levers in which the load, effort, and fulcrum are in different places in relation to each other. | 3.5, 3.6 |
| When the forces exerted on an object are unbalanced, the speed and/or direction of the object will change, otherwise there is no change in motion. | 3.3, 3.4 |

# Understanding for Teachers

In this *Learning Set*, students are introduced to three machines: The lever, the pulley, and the wheel and axle. The wheel and axle is a variation of the pulley. This machine, like all machines, can change the amount of applied force and/or its direction to make completion of a task easier.

## The Lever

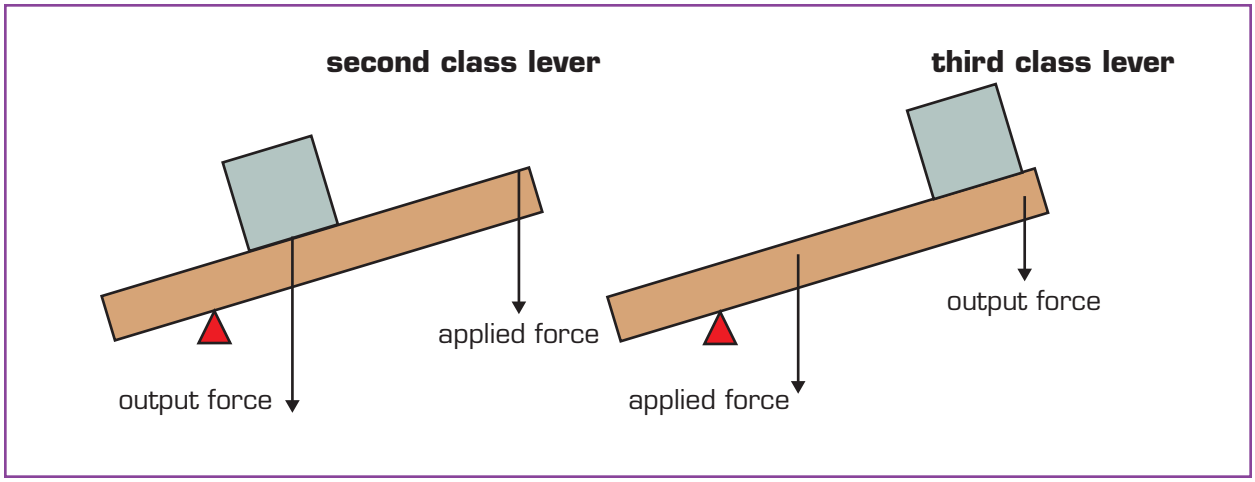
The lever can change the force and direction of the applied force. It may increase, decrease, or keep the force the same and can change the direction by 180˚. The lever shown below is used to lift a pile of blocks.




The point where the lever pivots is called the fulcrum. The mechanical advantage of a lever can be changed by repositioning the fulcrum. If the fulcrum is placed near the load, less force is needed to lift it, but the force will need to be applied over a greater distance. If the fulcrum is near the applied force, it takes more force to lift the object, the lever arm moves a smaller distance, and the object being moved moves through a greater distance.

Levers are commonly placed in three categories, or "classes", depending on where the fulcrum is located in relation to where the force is applied. First-class levers are thought of as the most common type of levers. A first-class lever is shown in the image above. A second-class lever is one where the load is placed between the applied force and the fulcrum. In this case, the direction of the applied force and the direction that the load moves are the same. Examples of second-class levers are a nut cracker, a crowbar, and a wheelbarrow. For the wheelbarrow, the handles move a greater distance than the load, but you have to apply less force to lift the load.

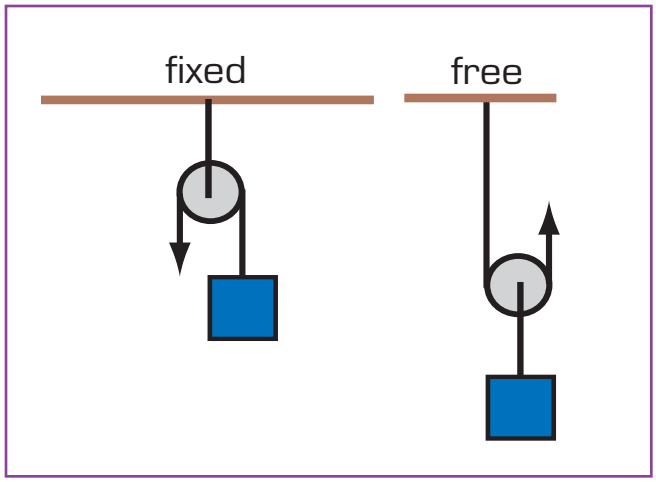
A third-class lever is one where the applied force is between the fulcrum and the load. A broom or rake is an example of a third-class lever, with the fulcrum at the very top of the handle. This type of lever does not change the direction of the force. Third-class levers are used to increase the speed and distance an object moves in, and the output force is less than the applied force. In some cases, it is easier to apply large amounts of force through a small distance, such as when raking the lawn. Moving dry leaves does not take a lot of force, but it is difficult to apply it over such a large area. By applying a larger force through a smaller distance, the task becomes easier.




It is not necessary that students be able to name levers as first, second, or third class. However, students should be able to identify objects that consist of the different types of levers.

## The Pulley

The different types of pulleys have different mechanical advantages, depending on how the pulley is set up. The image below shows how a fixed pulley and a free pulley can be used to lift a block. Ideally, a single fixed pulley simply changes the direction of the applied force, and does not reduce it (the amount of force and the amount of distance are the same both with and without a fixed pulley). A free pulley distributes the force across both sides of the pulley since the load is supported by the string on each side. This results in the amount of force needed to lift the block being half that of a free pulley. However, the distance the force is applied through is twice as much, because there is twice as much string to pull.




Combinations of pulleys can be put together in the form of pulley systems and block and tackle systems. The mechanical advantage is directly related to the number of strings that support the weight of the load—more pulleys result in a higher number of support threads, lower applied force and greater distance of the applied force.

## The Wheel and Axle

A wheel and axle works by increasing the turning distance while decreasing the amount of force that is applied. A steering wheel is one example of a wheel and axle. The force applied to the outside edge of the wheel is small compared to the force applied to turn the axle, but the edge of the wheel must move through a much greater distance than the axle moves.

The mechanical advantage of a wheel and axle can be changed by increasing the ratio between the diameter of the wheel and the diameter of the axle. In other words, increasing the size of the wheel or decreasing the size of the axle (or both) will decrease the amount of applied force needed to move the axle. There is, however, an increase in distance due to the increased circumference (outside edge) of the wheel.

NOTES

# LEARNING SET 3 IMPLEMENTATION

## Learning Set 3

### What Other Machines Can Change Force?

*5 min.*

*Introduce the* Learning Set.

## Learning Set 3

### What Other Machines Can Change Force?

You have learned about three simple machines—the inclined plane, the wedge, and the screw. You learned that the wedge and the screw are actually variations of the inclined plane. Each of these simple machines can increase a force to make an object move. Machines allow people to move big things that they could not move on their own.

If you look around, you would be able to quickly find an example of each. There may be a flag in front of your school. Each day, the flag is raised and lowered using a pulley. At a playground, you are likely to see a seesaw. This simple board, balanced on a support in the middle, is an example of a lever. If you turn a doorknob to open a door, you are using a wheel and axle!

MBT 66

*Project-Based Inquiry Science*

## Engage

Briefly elicit students' ideas about the lever, the pulley, and the wheel and axle and how they might help the challenge.

**TEACHER TALK**

"We're going to be learning about the pulley, the lever, and the wheel and axle in this *Learning Set*. What do you think these are and where have you seen them used?"

Then provide some examples of a pulley (e.g., flagpole—to raise and lower a flag), lever (e.g., a seesaw, nut cracker) and, wheel and axle (e.g., a doorknob).