LEARNING SET 2 INTRODUCTION

Learning Set 2

How Can a Machine Change a Force?

◀ $6\frac{1}{2}$ class periods*

Exploring how an inclined plane helps lift a weight, students see a trade-off between the force required to lift something and the distance they have to move it and learn about mechanical advantage. They read about wedges and screws and see how mechanical advantage works in these machines.

Overview

Now that students have determined how unbalanced forces can make something move, they can begin to identify how machines can change force. Students begin by thinking about how machines change force and then read about Newton's Laws. Then students investigate the force needed to lift a weight and then the force needed to lift the weight up inclined planes of varying steepness. Students measure the amount of force and the distance traveled as part of their procedure. Using graphs of the data, students compare force and distance and begin to understand qualitatively the mechanical advantage of machines. Students create an explanation of how an inclined plane does its job using the evidence from their investigations to support their explanation. After reading about wedges and screws and how these machines also have mechanical advantage, students revise their explanation using the additional information about mechanical advantage. Students learn the definition of work and apply this definition to a problem. The term work is then used for the remainder of the Unit. Ultimately, students will use their knowledge of machines to build a machine that can lift the crate with a thin thread. The next step in this process is for students to plan a design to lift the crate using an inclined plane. They share their plans with the class and have a chance to build a model of their plan. Finally, students add what they have learned about three simple machines, mechanical advantage, and work to 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	2.1, 2.2, 2.3, 2.5, BBQ
Criteria and constraints are important in design.	BBQ
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.	2.2, 2.3, 2.5, BBQ
Graphs and tables are an effective way to communicate results of scientific investigation.	2.2
Identifying factors that lead to variation is an important part of scientific investigation.	2.1
Scientific investigations and measurements are considered reliable if the results are repeatable by other scientists using the same procedures.	2.2
In a fair test only the manipulated (independent) variable, and the responding (dependent) variable change. All other variables are held constant.	2.2
Scientists make claims (conclusions) based on evidence obtained (trends in data) from reliable investigations.	2.2, 2.3, 2.5
Explanations are claims supported by evidence, accepted ideas, and facts.	2.3, 2.5
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
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.	2.1, 2.3, 2.5
Machines provide mechanical advantage to assist in moving objects. Mechanical advantage is the trade-off between force and distance.	2.4, 2.5, BBQ
There are six different simple machines all of which provide mechanical advantage: Inclined plane, wedge, screw, wheel and axle, lever, and pulley.	2.2, 2.3, 2.4, 2.5, BBQ

Targeted Concepts, Skills, and Nature of Science	Section
Work only occurs when a force exerted on a moving object is applied in or opposite to the object's direction of motion.	2.5

Students' Initial Conceptions and Capabilities

- **Newton's Laws are introduced in this *Learning Set*, but are not developed until a later Unit. Nonetheless, you should be aware of students' initial ideas about these. Additional ideas are listed here:**

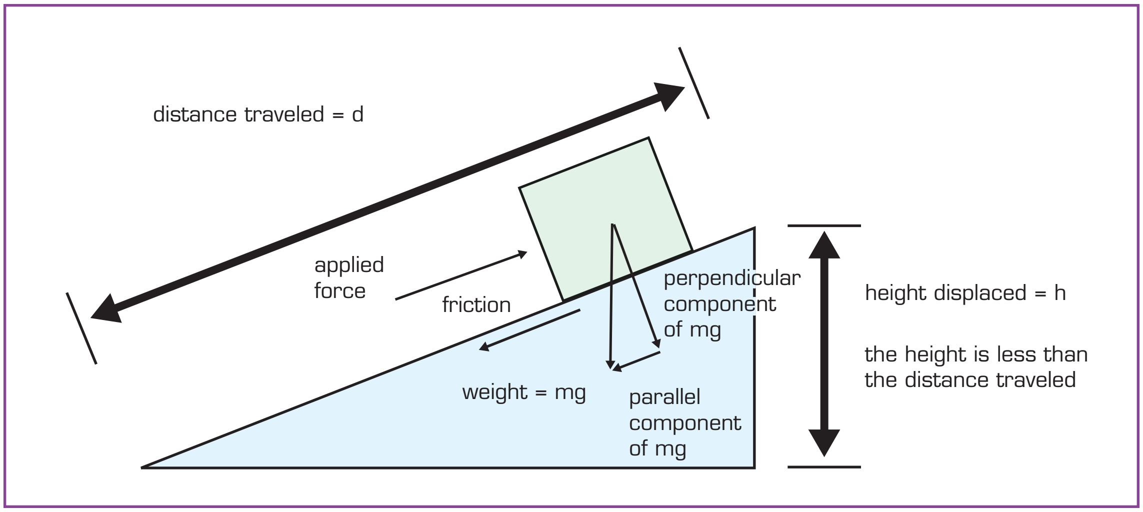
  For Newton's third law, some believe that the action force is greater than the reaction force. Many also believe that the action and reaction forces act on the same object.

Understanding for Teachers

Simple Machines

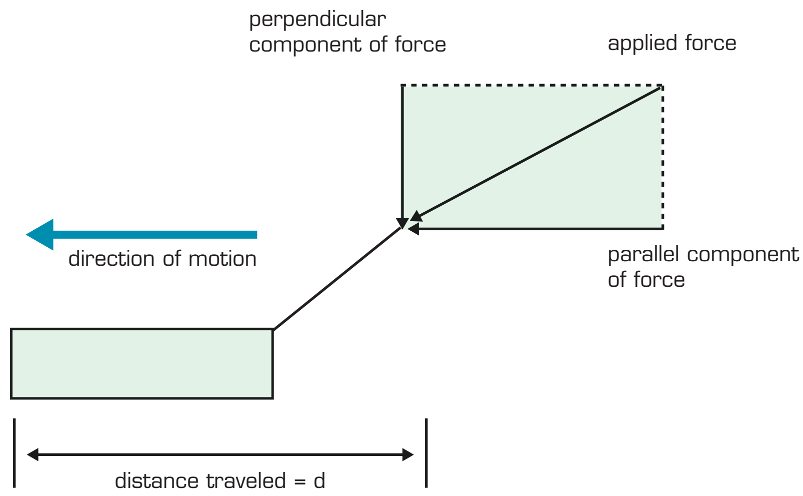
There are three basic simple machines: the incline plane, the lever, and the pulley. The wheel and axle is a type of pulley; wedges and screw are just modifications of the incline plane. The purpose of a machine is to help us achieve a task that would be difficult to do otherwise.

An inclined plane is a machine that helps to reduce forces needed to move objects against gravity, however, as with all machines there is a price to pay. The incline plane decreases the amount of force you need to apply to move an object, but it increases the distance you need to move it. This tradeoff between force and distance over which the force is needed is qualitatively the mechanical advantage.



Mechanical Advantage

Qualitatively, the mechanical advantage is the tradeoff between force and distance. Generally, the mechanical advantage is found by dividing the distance over which the force is applied by the distance the object is displaced. For an inclined plane this would be the distance of the incline divided by the height of the incline or, for the image above: MA = d/h



Work

A machine is a device that does work but cannot increase the amount of work done. Rather they are usually designed to make our task easier.

In science, work has a very particular definition. The work done by a force is equal to the amount of force parallel to the direction of motion multiplied by the distance the object moved.

Work done = force parallel to direction of motion × the distance the object moved

If a force is acting on an object in motion, but the force is perpendicular to the object's displacement, then that force does no work. For example, if you hold a heavy box in your arms but don't move, the force you apply does no work on the object. Below an example is provided of a person pushing a lawn mower.

Work done by applied force = parallel component of force × distance traveled

No work is done by the perpendicular component of the force in moving the lawnmower.

For more information you can search the Internet using key words such as, "simple machines" and/or "mechanical advantage."

2.1

LEARNING SET 2 IMPLEMENTATION

Learning Set 2

How Can a Machine Change a Force?

Your challenge is to design a model of a machine that will help the biologists, Drs. Enrique, Susan, and Tanika, lift their supply crate from the beach up to the top of the cliff. In *Learning Set 1*, you discovered that you must generate a force larger than the weight of the crate to move it up the cliff. However, by themselves, the biologists can only supply a small amount of force to lift the crate. This force is too small to move the crate up the cliff.

To lift the crate, you will need to make up the difference between this small force and the force of gravity pulling down on the crate. How can you do this? In this *Learning Set,* you will learn how a machine can help a small force move big things.

The pictures show some large structures typically found in large cities—a high-rise building, a baseball stadium, and a bridge. These structures were obviously built with parts that a human would not be able to lift or move. As you saw on your construction walk, or in the construction video, people use machines to build structures such as these. When a person applies a small force to a machine, the machine applies a much larger force. The machine can apply a force large enough to move or lift something very heavy. In this *Learning Set,* you will find out how machines are able to do this.

Learning Set 2

How Can a Machine Change a Force?

5 min.

Introduce students to the question of this Learning Set: How can a machine change a force? *Engage students by getting them thinking about the many big things we would not be able to build without machines.*

○ Engage

Ask students for some of the largest structures they know about. Then ask them how they were built.

TEACHER TALK

"What are some really big buildings, or other structures? How do you think they were built? What did people use when they built them?"

META NOTES

Some prehistoric structures may come up, such as the pyramids of Giza. In that case, we cannot say how they were built. However, many researchers think that the pyramids were built using ramps—a kind of inclined plane.

NOTES