Simple Machines

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Lesson Focus
Simple machines: their principles and uses.

Lesson Synopsis
Students learn the basic principles of simple machines and explore everyday uses.

- Simple machines are "simple" because most have only one moving part.
- "Work" is only done when something is moved (displaced) by a force (push or pull).
- Machines do not reduce the amount of work for us, but they can make it easier.

Age Levels
8-14 - though can be adapted for older students.

Objectives

- Be able to identify simple machines and their use in daily life.
- Build a simple machine.
- Define work as an object being moved through a distance by a force.

Anticipated Learner Outcomes
As a result of the activities, all students should develop an understanding of:

- How the position and motion of objects can be changed by pushing or pulling. The amount of this displacement is directly related to the strength of the push or pull.

Simple Machines: Introduction

Simple machines are "simple" because most have only one moving part. When you put simple machines together, you get a complex machine, like a lawn mower, a car, even an electric nose hair trimmer! A machine is defined as any device that makes work easier. In science, "work" means making something move. It's important to know that when you use a simple machine, you're actually doing the same amount of work — it just seems easier. A simple machine reduces the amount of effort needed to move something, but you wind up moving it a greater distance to accomplish the same amount of work. So there's a trade–off of energy when using simple machines.

What does "work" mean in science?
Simple machines all require human energy in order to function. "Work" has a special meaning in science. "Work" is only done when something is moved. For example, when you push on a wall, you actually are not doing work, because you cannot move it. Work consists of two parts. One is the amount of force (push or pull) needed to do the work. The other is the distance over which the force is applied. The formula for work is:

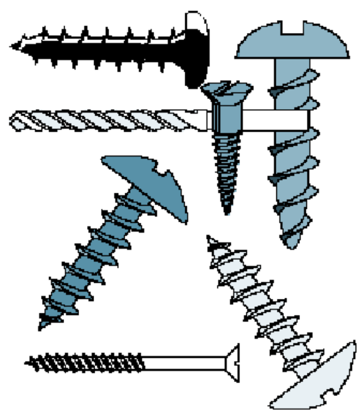
Work = Force X Distance

Force is the pull or the push on an object, resulting in its movement. Distance is the space the object moves. Thus, the work done is the force exerted multiplied by the distance moved.

When we say a machine makes it easier for us to do work, we mean that it requires less force to accomplish the same amount of work. Apart from allowing us to increase the distance over which we apply the smaller force, machines may also allow us to change the direction of an applied force. Machines do not reduce the amount of work for us, but they can make it easier.

Types of Simple Machines
See Handout.

Lesson Activities



Three student handouts are provided for advance review:

- Introduction To Simple Machines
- Types of Simple Machines
- What is Work? (Worksheet)

Four student activities are provided:

- Are These Machines?
- Jumping Coin Experiment
- Make Your Own Inclined Plane
- You are the Engineer: Problem Solving with Simple Machines

Resources/Materials

See attached student worksheets and teacher resource documents.

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Recommended Reading

- What Are Inclined Planes? (Looking at Simple Machines) by Helen Frost. Publisher: Pebble Books; (January 2001) ISBN: 0736808450
- Simple Machines (Starting With Science) by Adrienne Mason, Deborah Hodge, the Ontario Science Centre (Publisher: Kids Can Press; (March 2000) ISBN: 1550743996
- Science Experiments With Simple Machines (Science Experiments) by Sally Nankivell-Aston, Dorothy Jackson (Publisher: Franklin Watts, Incorporated; (September 2000) ISBN: 0531154459
- Janice VanCleave's Physics for Every Kid: 101 Easy Experiments in Motion, Heat, Light, Machines, and Sound, by Janice VanCleave. John Wiley & Sons ISBN: 0471525057

Optional Writing Activity

- Identify examples of simple machines at home. Write an essay (or paragraph depending on age) about how the simple machine makes life easier for someone in the family.

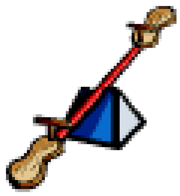
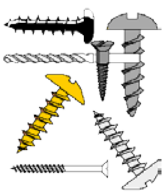
References

Mike Ingram and volunteers from
Chattanooga, TN USA Section of IEEE
URL: http://ewh.ieee.org/r3/Chattanooga

Carole Kalb Levy B.S. M.A. PD
IEEE Educational Activities

Simple Machines

For Teachers: Are These Machines?

	Teacher Notes: A teeter-totter or seesaw is an example of a class-one lever. The balance point, or fulcrum, is somewhere between the applied force and the load. This type of lever (class one) has three parts: the balance point or fulcrum, the effort arm where the force or work is applied, and the resistance arm where the object to be moved is placed.
	Teacher Notes: The nail bar is also a lever, but it is a class-two lever (if you use the right end of the nail bar shown in the picture). A class-two lever is a lever with the effort and resistance forces on the same side of the fulcrum. To pry the nail with the right end of the bar shown, the fulcrum is the tip, the nail head applies a resistive force, and at the opposite end is the effort or work. Another example of a class-two lever is a wheel barrow.
	Teacher Notes: The wheel chair ramp is an inclined plane. Although the distance up the ramp is greater than the distance straight up, less force is required. Use the formula to determine how it could be the same amount of work.
	Teacher Notes: The screw is actually just another kind of inclined plane. It is basically an inclined plane that is wrapped around a cylinder.
	Teacher Notes: A fishing pole is a very good example of a third class lever. In this class of levers, the force arm lies between the fulcrum and the load arm. Because of this arrangement, a relatively large force is required to move the load. This is offset by the fact that it is possible to produce movement of the load over a long distance with a relatively small movement of the force arm. Think of a fishing rod! Because of this relationship, we often employ this class of lever when we wish to produce large movements of a small load, or to transfer relatively low speed of the force arm to high speed of the load arm. When a hockey stick or a baseball bat is swung, a third class lever is in effect. The elbow acts as a fulcrum in both cases and the hands provide the force (hence the lower arm becomes part of the lever). The load (i.e. the puck or the ball) is moved at the end of the stick or bat. Example of third class levers are: a fishing pole, a pair of tweezers, an arm lifting a weight, a person using a broom, a hockey stick, a tennis racket, a spade, or a shovel.

For Teachers:
Resource Chart

SIMPLE MACHINES	WHAT IT IS	HOW IT HELPS US WORK	EXAMPLES
LEVER	A stiff bar that rests on a support called a fulcrum	Lifts or moves loads	Nail clipper, shovel, nutcracker, seesaw, crow-bar, elbow, tweezers, bottle opener
INCLINED PLANE	A slanting surface connecting a lower level to a higher level	Things move up or down it	Slide, stairs, ramp, escalator, slope
WHEEL AND AXLE	A wheel with a rod, called an axle, through its center: both parts move together	Lifts or moves loads	Doorknob, pencil sharpener, bike
PULLEY	A grooved wheel with a rope or cable around it	Moves things up, down, or across	Curtain rod, tow truck, mini-blind, flag pole, crane

Typically, machines are intended to reduce the amount of force required to move an object. But in the process, the distance is increased. A wheel chair ramp is easily visualized example of this relationship. While the amount of effort and strength is reduced (force) the actual distance is significantly increased. Therefore, the amount of actual work is the same.

While the typical application of machines is to reduce effort or force, there are important applications of machines where this is no advantage – that is force is not reduced, or there is actually a decrease in advantage – that is, force is increased.

The best example of a machine that provides no advantage is a simple or single pulley. A single pulley only changes the direction of the effort force. A curtain pull is an example.

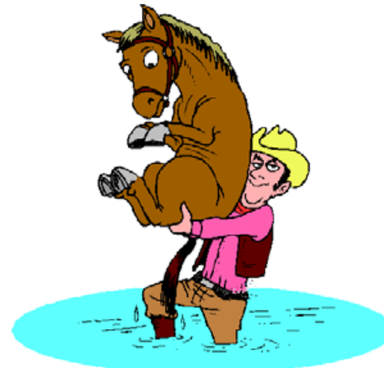
Simple Machines

Teacher Resource

What is Work? (Solution to Student Worksheet)

Work is the product of the force exerted on an object and the object's displacement due to that force. The formula to describe this is:

Work = Force x distance

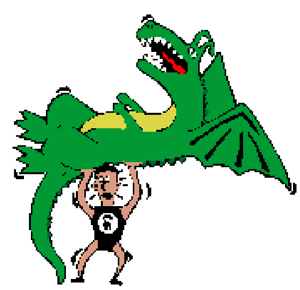


Work is measured in joules, J (after James Prescott Joule). Force is measured in newtons, N (after Sir Isaac Newton). (The formula for force is mass X acceleration. So the pull of gravity should actually be taken into account when using the mass of an object to calculate work. The force should be measured as $kg.m/sec^2$ or Newtons. For the younger audience we should just use mass or kg. as force. For older students the actual weight or Newtons should be calculated.) Distance is measured in meters, m.

In this equation, however, the force only counts if it is in the direction that the object is moving. As an example, consider if you lifted a heavy horse and carried the horse across a river. When you have crossed the river, the only work you have done was lifting the horse. Crossing the river while holding the horse added nothing to the amount of work you did. Keep in mind that applying force to an object doesn't always equal work being done. If you sit on your bicycle, you apply force on the seat, but no work is being done because your force on the seat is not causing displacement. But, if you applied force to the chair by lifting it up off the floor, they your force produces displacement in the direction of motion - and work has been done.

The distance an object moves is another factor to be considered when calculating work. For a ball (for example) to move a distance from its original position, requires work to be done on the ball. And, distance is directional. This means that if you move an object in a positive direction, you have done positive work. If you move it in a negative direction, you have done negative work.

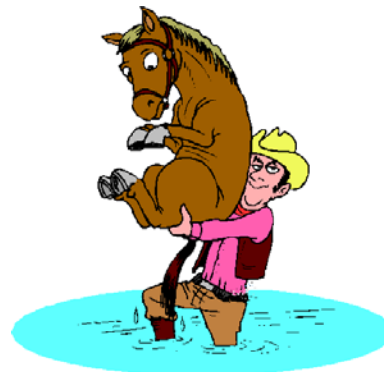
Student Question A:
A 45kg girl sits on an 8 kg bench. How much work is done on the bench?
Solution: None. The girl applies a (45) Newton force on the bench, but it does not cause it to move. So, the distance traveled due to her force is zero and Work = Force x Distance, so (45)(0) = 0. (Again for the older students the force should be the mass times the acceleration of gravity 9.8 m/sec^2.)



Student Question b:
A 40kg boy lifts a 30kg dragon 2 meters above the ground. How much work did the man do on the dragon?
Solution: The boy applies a force that results in the dragon moving a distance of 2 meters. Therefore, Work = Force x Distance implies Work = (30)(2) = 60 Newton meters or Joules (1 Newton meter = 1 Joule). (Again for the older students the force should be the mass times the acceleration of gravity 9.8 m/sec^2.)

What is Work? - Student Worksheet

Work is the product of the force exerted on an object and the object's displacement due to that force. The formula to describe this is:



Work = Force x distance

Work is measured in joules, j (after James Prescott Joule).
Force is measured in newtons, N (after Sir Isaac Newton).
Distance is measured in meters, m.

In this equation, however, the force only counts if it is in the direction that the object is moving. As an example, consider if you lifted a heavy horse and carried the horse across a river. When you have crossed the river, the only work you have done was lifting the horse. Crossing the river while holding the horse added nothing to the amount of work you did. Keep in mind that applying force to an object doesn't always equal work being done. If you sit on your bicycle, you apply force on the seat, but no work is being done because your force on the seat is not causing displacement. But, if you applied force to the chair by lifting it up off the floor, they your force produces displacement in the direction of motion - and work has been done.

The distance an object moves is another factor to be considered when calculating work. For a ball (for example) to move a distance from its original position, requires work to be done on the ball. And, distance is directional. This means that if you move an object in a positive direction, you have done positive work. If you move it in a negative direction, you have done negative work.

Student Question A:
A 45kg girl sits on an 8 kg bench. How much work is done on the bench?
Remember that work = force x distance.
What is the distance? What is the work?

Student Question b:
A 40kg boy lifts a 30kg dragon 2 meters above the ground. How much work did the boy do on the dragon?
Remember that work = force x distance.
What is the distance? What is the work? What do we need to include?

Introduction To Simple Machines

Simple machines are "simple" because most have only one moving part. When you put simple machines together, you get a complex machine, like a lawn mower, a car, even an electric nose hair trimmer! Remember, a machine is any device that makes work easier. In science, "work" means making something move. It's important to know that when you use a simple machine, you're actually doing the same amount of work -- it just seems easier. A simple machine reduces the amount of force needed to move something, but what must you increase to keep the work the same?

What does "work" mean?

Simple machines all require human energy in order to function. "Work" has a special meaning in science. "Work" is only done when something is moved. For example, when you push on a wall, you actually are not doing work, because you cannot move it. Work consists of two parts. One is the amount of force (push or pull) needed to do the work. The other is the distance over which the force is applied. The formula for work is:

Work = Force X Distance

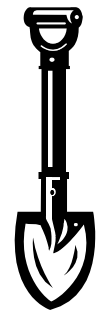
Force is the pull or the push on an object, resulting in its movement. Distance (Displacement) is the space the object moves. Thus, the work done is the force exerted multiplied by the distance moved.

When we say a machine makes it easier for us to do work, we mean that it requires less force to accomplish the same amount of work. Apart from allowing us to increase the distance over which we apply the smaller force, machines may also allow us to change the direction of an applied force. Machines do not reduce the amount of work for us, but they can make it easier. How?

Types of Simple Machines

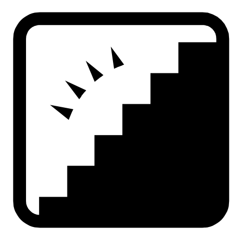
There are four types of simple machines which form the basis for all mechanical machines:

- **Lever**

  Try pulling a really stubborn weed out of the ground. Using just your bare hands, it might be difficult or even painful. With a tool, like a hand shovel, however, you should win the battle. Any tool that pries something loose is a lever. A lever is an arm that "pivots" (or turns) against a "fulcrum" (or point). Think of the claw end of a hammer that you use to pry nails loose. It's a lever. It's a curved arm that rests against a point on a surface. As you rotate the curved arm, it pries the nail loose from the surface. And that's hard work! There are three kinds of levers:
    - First Class Lever - When the fulcrum lies between the force arm and the lever arm, the lever is described as a first class lever. In fact many of us are familiar with this type of lever. It is the classic teeter-totter example.
    - Second Class Lever - In the second class lever, the load arm lies between the fulcrum and the force arm. A good example of this type of lever is the wheelbarrow.
    - Third Class Lever - In this class of levers, the force arm lies between the fulcrum and the load arm. Because of this arrangement, a relatively large force is required to move the load. This is offset by the fact that it is possible to produce movement of the load over a long distance with a relatively small movement of the force arm. Think of a fishing rod!

- **Inclined Plane**

  A plane is a flat surface. For example, a smooth board is a plane. Now, if the plane is lying flat on the ground, it isn't likely to help you do work. However, when that plane is inclined, or slanted, it can help you move objects across distances. And, that's work! A common inclined plane is a ramp. Lifting a heavy box onto a loading dock is much easier if you slide the box up a ramp--a simple machine.

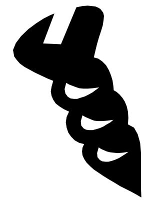
    - **Wedge**

      Instead of using the smooth side of the inclined plane, you can also use the pointed edges to do other kinds of work. For example, you can use the edge to push things apart. Then, the inclined plane is a wedge. So, a wedge is actually a kind of inclined plane. An axeblade is a wedge. Think of the edge of the blade. It's the edge of a smooth slanted surface. That's a wedge!

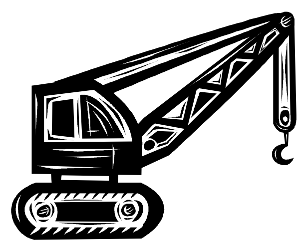
Types of Simple Machines (continued)

- **Screw**
  Now, take an inclined plane and wrap it around a cylinder. Its sharp edge becomes another simple tool: the screw. Put a metal screw beside a ramp and it's kind of hard to see the similarities, but the screw is actually just another kind of inclined plane. How does the screw help you do work? Every turn of a metal screw helps you move a piece of metal through a wooden space.



- **Wheel and Axle**
  A wheel is a circular disk attached to a central rod, called an axle. The steering wheel of a car is a wheel and axle. The section that we place our hands on and apply force (torque) is called the wheel, which turns the smaller axle. The screwdriver is another example of the wheel and axle. Loosening a tight screw with bare hands can be impossible. The thick handle is the wheel, and the metal shaft is the axle. The larger the handle, the less force is needed to turn the screw.

- **Pulley**
  Instead of an axle, the wheel could also rotate a rope or cord. This variation of the wheel and axle is the pulley. In a pulley, a cord wraps around a wheel. As the wheel rotates, the cord moves in either direction. Now, attach a hook to the cord, and you can use the wheel's rotation to raise and lower objects. On a flagpole, for example, a rope is attached to a pulley. On the rope, there are usually two hooks. The cord rotates around the pulley and lowers the hooks where you can attach the flag. Then, rotate the cord and the flag raises high on the pole.

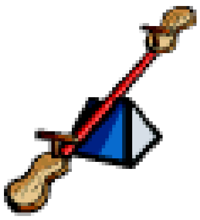


Simple Machines

Student Worksheet

Are These Machines?

Examine the drawings below and try to determine whether these are simple machines. See if you can figure out what type of simple machine it might be: class-one lever, class-two lever, third class lever, inclined plane.

	Notes:
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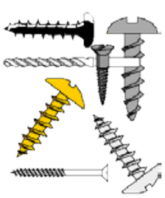	Notes:
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Jumping Coin Experiment

Purpose:
To find out where to push on a lever to get the best lift.

Materials:

- ruler
- pencil
- two large coins

Procedure:

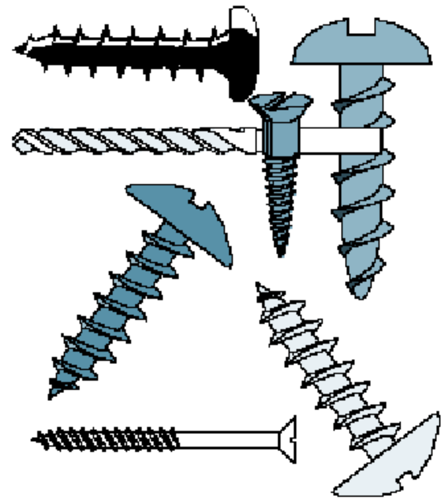
- Put the pencil under the ruler and place a coin on one end.
- Drop another coin from a height of 30 cm so it hits the ruler at about the 8 cm mark. Notice how high the coin jumps in the air.
- Repeat the coin drop but drop it at the end of the ruler from the same height. Observe how high the coin jumps.

Questions:

What would happen if you put an object with a larger diameter than the pencil under the ruler?

Try this experiment: Move the pencil to several different locations under the ruler, then repeat the experiment. How were your results different/the same?

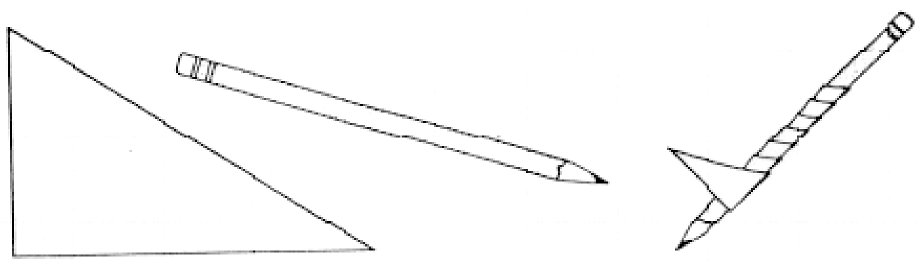
Make Your Own Inclined Plane



Objectives:
Show that a screw is an inclined plane.

Materials:
- paper
- pencil
- tape
- crayon

Procedure:
- Give each student a paper right-triangle and have the longest side colored.
- Tape one of the uncolored sides of the triangle to the pencil.
- Wrap the triangle around the pencil and tape down.
- The triangle wraps in a spiral



Lesson Details:
- Explain about incline planes and show examples of several, including how they make life easier, or reduce work.

Student Worksheet: You are the Engineer! Problem Solving with Simple Machines

◆ **Instructions**

You are the engineer! Work in a team and devise a plan using simple machines to help a large dog with back problems get into the back of a pick up truck or SUV. The dog cannot jump on its own, and is too heavy for the owner to lift.

Step One:

Draw your team's machine or solution in the box below.

Step Two:

Make a working model of your design using parts you can find in your classroom, or that you used in prior worksheets in this lesson. Don't worry if your model is not to scale and cannot really support the weight of an actual dog -- engineers work in different scales all the time!

Step Three:

As a team, brainstorm and think of two other situations where the solution you came up with might be helpful to people or other animals. List them below:

1.

2.

Step Four:

Present your drawing, model, example of similar problems, and your solution to the class!

For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Properties of objects and materials
- ✦ Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities to distinguish between natural objects and objects made by humans

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Motions and forces
- ✦ Transfer of energy

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor
- ✦ History of science

◆Next Generation Science Standards Grades 2-5 (Ages 7-11)

Matter and its Interactions

- ✦ 2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- ✦ 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Engineering Design

Students who demonstrate understanding can:

- ✦ 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- ✦ 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

For Teachers:
Alignment to Curriculum Frameworks

◆Standards for Technological Literacy - All Ages

Technology and Society

- Standard 5: Students will develop an understanding of the effects of technology on the environment.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.