Lesson: **Mechanical Engineering: Simple Machines**

Grade Level: 8-9 – Time Required: 50 minutes – Lesson Dependency: None – Subject Areas:

* Geometry
* Physical Science
* Problem Solving
* Reasoning and Proof
* Science and Technology

Summary

Simple machines are machines with little or no moving parts that make completing work easier. The six simple machines are introduced and explained in the lesson, as an extension of mechanical engineering. Students are told of the importance of simple machines and how they’ve contributed to society over the centuries. The knowledge is simple with the previously mentioned explanations being kept basic. There is one hands-on activity and another virtual activity where students play an educational game about simple machines and learn about each along the way.

Engineering Connection

Engineers have been using simple machines for thousands of years, with continued usage up to modern times. Devices like highway ramps, shovels, door stoppers, ladders, etc. are commonplace and are used by all every day. The simplicity of simple machines allows even those who know nothing of engineering to solve problems that would have initially required an engineer to tackle. The same mathematical and physical concepts used by ancient engineers are still employed by engineers today to solve complex problems and construct structures.

Learning Objectives

Upon the completion of this lesson, students should be able to:

* Know what simple machines are and how they are used
* Know why they are used
* Know the importance of simple machines
* Be able to name all six simple machines and determine what type of simple machine a device is or employs (i.e. they should be able to determine that stairs are inclined planes)
* Be able to solve basic engineering problems with simple machines

### Educational Standards

* [MA.912.AR.1.1](https://www.cpalms.org/Public/PreviewStandard/Preview/15555) - Identify and interpret parts of an equation or expression that represent a quantity in terms of a mathematical or real-world context, including viewing one or more of its parts as a single entity.
* [MA.912.AR.1.2](https://www.cpalms.org/Public/PreviewStandard/Preview/15556) - Rearrange equations or formulas to isolate a quantity of interest.
* [CTE-TECED.68.ENGTEC.02.02](https://www.cpalms.org/Public/PreviewStandard/Preview/14494) - Identify Simple Machines
* [CTE-TECED.68.ENGTEC.02.03](https://www.cpalms.org/Public/PreviewStandard/Preview/14495) - Explain Mechanical Advantage

Worksheets and Attachments

[Simple Machines Presentation](https://docs.google.com/presentation/d/1U6ieo8bSQD_JhbiFr8agn9W8F768oAZ1KzGapO2nW_s/edit?usp=sharing)

[Mechanical Advantage Formula Worksheet](https://docs.google.com/document/d/1yLWrZiXesYA8IGiCh6NJwImgqF_FlKq1paEJZYrOHOI/edit?usp=sharing)

[MA Quick Question Worksheet](https://docs.google.com/document/d/19MR3em-sFIN9e8jyTu3thIBiHAfp81TcLgtZ2ZPXHbU/edit?usp=sharing)

[MA Quick Question Answer & Explanation](https://docs.google.com/document/d/1pLZqmvTHUY6_wlXaaxWfBZsov6cEfv8fZWXcJ0lmnsc/edit?usp=sharing)

Introduction/Motivation

The continued use of simple machines has been going on for thousands of years. While the idea of simple machines originated from the Greek philosopher Archimedes around the 3rd century BC, there is evidence that usage of simple machines dates as far back as 1.2 million years, when our ancestors, *Homo erectus*, created the wedge, making it the oldest known simple machine. Another example of a simple machine that predates the idea of simple machines is the inclined plane, which was used in the construction of the Great Pyramids around 2,500 BCE. Archimedes and later Greek philosophers would eventually discover the mechanical advantages for each simple machine, but the concept of work would be developed later. The Renaissance allowed for more extensive research and study of simple machines, which led to the new concept of work and the idea that a simple machine transforms energy, rather than create it.

Simple machines also play an integral role in mechanical engineering since the discipline involves anything that has moving parts to it. While some of the simple machines, such as the wedge, inclined plane, and screw may not have any moving parts, they are, however, used as parts of complex machines. Complex machines are machines that utilize two or more simple machines. Bicycles and airplanes, two types of complex machines, use pulleys, the wheel and axle, the screw, and a lever. Even more complex machines like a car use all six. Knowing this information, simple machines are important to aspiring mechanical engineers because knowing how to implement each, along with calculating their respective mechanical advantages, is crucial to success in that field.

The purpose of including simple machines as a lesson in the mechanical engineering presentation is to introduce the concept of them to the students and prepare them for future engineering classes. By going in with prior knowledge, these students will be able to grasp concepts relating to simple machines easily and quicker than those who go in with little or no prior knowledge on the subject.

(Transition into the presentation slides relating to simple machines by using the script provided in Lesson Background)

Lesson Background and Concepts for Teachers

(The text that follows relates to the [Simple Machine Presentation](https://www.slideshare.net/mar_yoom/simple-machines-presentation) of the Mechanical Engineering Unit. Additionally, the script is meant to be an aid to the presenter rather than what they should say verbatim. The goal is for the presenter to put the information in their own words as best they can while still making it easy to understand. Presenters are not recommended to read off the slides.)

**Slide 1 –** (students should have now returned from their break time) All right, I hope you all were able to enjoy your time to unwind, but now it is time for us to go into the next section of our presentation: Simple Machines! Now, who here can tell me what the six simple machines are? You could also tell me one and provide an example of an object that is or uses a simple machine. (respond accordingly to the student given responses, after they have given their answers, if any, move on to the next slide)

**Slide 2 –** Okay! Simple machines are very basic machines with very little moving parts that allow us to do work more easily and efficiently. Notable features of simple machines are but are not limited to: not needing to use electricity, having one or no moving parts, or giving us a mechanical advantage by changing the force, direction, or speed of a movement. They amplify the force you apply on something to get it to move up, down, or side to side more easily.

**Slide 3 –** You may ask “why are they so important?” Well, simple machines have been used by people for thousands of years now, with no end in sight! While the general idea of simple machines originated from the Greek philosopher Archimedes in the 3rd century BC, historians and engineers alike have been made to believe that the use of simple machines goes back farther. It is believed that between 3000 and 2000 BC, simple machines, like the lever and wedge, were used to lift the large stones at Stonehenge into place. And of course, simple machines are useful because they reduce the amount of effort needed to perform tasks beyond their normal capabilities.

**Slide 4 –** Okay be sure to take a picture of this for later reference! Here are the six simple machines. The wheel and axle make moving objects across a distance by rolling. Inclined planes are flat surfaces that are slanted, or inclined so that you can move objects up to a certain with ease. Wedges are two inclined planes merged back to back to push things apart or break them in two. Levers are any rigid beams that are used to lift things when it is on a pivot point or pries something loose. A pulley is a wheel that has a groove with a cord passing through it. A screw is a cylinder with an inclined plane wrapped around it.

**Slide 5 –** All right, for our first activity, we want you to find one example of a simple machine in your house and then present it to us and provide a picture. You are to name the simple machine that it is and explain why. We will allocate 10 minutes for this activity. (once students have found examples, have them present them to each other for the remainder of the time) Okay now that you all have presented, I will now go in-depth as to what each simple machine is.

**Slide 6 –** Okay, now that we have seen some real-world examples, it’s time to figure out what is mechanical advantage. It is the ratio of the output force from the machine to the input force initially applied to it. In other words, the force that comes out of the machine divided by the force you put in. It is, in non-math terms, the advantage you get when using a simple machine, which decreases the effort needed to complete a task, making it easier. To the right are the formula and the different ways you can find the other two variables. However, there are two types of mechanical advantage and specific formulas for each machine. Be sure to take a picture for future reference.

**Slide 7 –** Before we get into the two types, we need to learn the terminology. “MA” can be also be defined as the ratio of the magnitude of the resistance (load) and effort forces, or the ratio of the distance traveled by the effort and the resistance force. Basically: the first is the resistance force divided by the effort, and the second is the distance of the effort divided by the distance of the resistance. There are also different ways of finding the other two variables. These two methods allow for more specific formulas. Be sure to take a picture for future reference.

**Slide 8 –** Now we get into the two types of mechanical advantage: Ideal and Actual. IMA is a theory-based calculation that doesn’t consider friction loss. This means that it is an estimate or expectation of what the MA should be in ideal conditions. IMA uses the ratio of distance traveled by effort and resistance force. Since we don’t live in an ideal world, AMA is used to determine the real MA. It’s based on calculations that use the forces and considers frictional losses. It uses the ratio of the magnitude of the resistance and effort forces. Below each description are the formulas for each, please do take a picture of each.

**Slide 9 –** Time for a quick question! Garrido is teaching his Intensive-POE class how levers work and demonstrate it by lifting a box with a 1st class lever. When he applies pressure on one end, the box lifts quickly and with ease. If Garrido is applying 15lbs of force and there is an AMA of 2.1, what is the weight of the box? Be sure to show your work. We will provide you with the link to the formula worksheet and the question worksheet. You will have five minutes to complete this, you will turn in your work to the email shown. After, we will discuss what the right answer is. (after the students finish the worksheet) Alright, how did you guys think you did? Well, for all those who got the answer of 31.5, you were correct! As for those who didn’t, let me explain: In this situation, the pressure Garrido puts on one end of the lever is the effort force, while the box is the resistance force. Since both the effort force and AMA are given, we can calculate the resistance force by manipulating the equation. By multiplying the AMA with the effort force, we get 31.5, which in this situation means that the box weighs 31.5lbs. I hope you all understand now, do any of you any questions, however?

**Slide 10 –** Okay I think we need to take a 5-minute break from all this, I know I do! So, please take the time now to use the bathroom, ask questions, or just relax. Check back in after 5 minutes!

**Slide 11 –** The first simple machine we will go over is the wheel and axle. A wheel and axle are a simple machine that uses rolling motion to move objects more efficiently. A wheel is a disk that an axle is attached to and an axle is a cylindrical rod that is attached at the center of the wheel. You may also attach another wheel at the other end. The IMA of the wheel and axle is the radius of the effort divided by the radius of the resistance. It can be either the wheel or axle depending on what’s lifting the load and what is being turned. The image above shows how the forces may act on the wheel and axle. You encounter the wheel and axle every single day. As you can see, doorknobs are an example of the wheel and axle. Another example is their use in carts and cars. Tell me, would it be easier to move a cart with heavy objects without the wheel and axle or with it. (answer should be with it) Exactly, you would need a wheel and axle to easily move the cart.

**Slide 12 –** Next is the inclined plane. In simple terms, it is a flat surface that is higher at one end then it is at the other so that you can push objects upward without the need to physically lift them. Also, take note of the image on the left. As you can see, the longer the inclined plane, the greater the mechanical advantage. In other words, you exert less force. If you were to try to lift something that is 500 lb. using the smaller ramp, you wouldn’t get too far, that is unless you have super strength. Inclined planes can also be used to gently move objects down rather than just drop them. The IMA of an inclined plane is the length of the slope divided by the height. A fun example of an inclined plane is the slides on the right! Also, did you know that ladders and stairs are also types of inclined planes? Surprising, isn’t it?

**Slide 13 –** Now it’s time to talk about the wedge. One of the oldest simple machines, the wedge is two inclined planes fused back to back. They change the direction of the force applied to split things. In the example to the right, the downward force that is applied is separated into diagonal downward forces, which separates that trunk of the tree. An example of a wedge is an ax, but doorstoppers are also an example of a wedge. They demonstrate that wedges can also be used to keep objects in place.

**Slide 14 –** The IMA of a Wedge is the length perpendicular to the height divided by the height. I know that may sound confusing, which is why we included the picture on the left so that you know what we are referring to.

**Slide 15 –** Levers are rigid beams or planks that rotate freely on a pivot, which is also known as the fulcrum. The four parts of a lever are:

* The beam/plank.
* The fulcrum, which is the point on the part that creates a pivot.
* Then there is the effort that is applied; i.e. you press down on the lever and,
* Finally, the load, which is any object that needs to be lifted; can also be known as the output force.

There are three classes of levers depending on the location of the effort, load, and fulcrum. Despite that, they all share the same IMA formula: the length from the fulcrum to the effort divided by the length from the fulcrum to the resistance.

**Slide 16 –** A first-class lever is a lever in which the fulcrum is between the load and effort. The closer the load is the fulcrum, the greater the mechanical advantage. The farther the effort is from the fulcrum, the greater the mechanical advantage. For the first-class lever, it is easy to find the IMA due to the placement of the resistance and the effort. Two notable examples are scissors and seesaws.

**Slide 17 –** In a second-class lever, the load is between the fulcrum and the effort. Similarly, as with the first-class, the mechanical advantage is greater the closer the load is to the fulcrum. An example of a second-class lever is a wheelbarrow as depicted in the graphic to the right. The IMA may seem hard to understand due to the overlapping, but in reality, it is easy as all you do is get the lengths and divide how you normally would. Now we will move on to the final class.

**Slide 18 –** Third-class levers are the final type of lever in which the effort is between the load and the fulcrum. Unlike the previous two, the closer the effort is to the fulcrum, the greater the mechanical advantage. While the shovel depicted is an example of a third-class lever, your arm is an example of a third-class lever. Your elbow is the fulcrum, your hand holds the load, a ball is a good example, and where the bicep connects to the upper part to your lower arm (the part closest to your elbow) is the effort. The situation with the IMA is the same as the second-class and is just as easy as the previous two. Now that we are done with levers, let’s move on to the next simple machine.

**Slide 19 –** A pulley is a wheel with a groove that has a cord, rope, or chain, pass through it. It is used to support movement and change of direction. The pulley is used primarily to lift heavy objects with greater ease. This is done by changing the direction of the force. For example, if you are lifting a box off the ground with a pulley, you will be able to lift the object by pulling the cord downwards. This will then pull the box upwards. The more pulleys you have, the greater the mechanical advantage.

**Slide 20 –** The IMA of the pulley is the least complicated than the others in my opinion, mostly because no arithmetic is used in its “calculations.” There three ways pulleys can be oriented, with these being the first two. Fixed pulleys have an IMA of 1, act like a first-class lever, and change the direction of the force. Movable pulleys, however, have an IMA of 2, act like second-class levers, and don’t change directions. As depicted in the first image on the left, if you try lifting a 10lb. box with a fixed pulley, you will need 10lbs. of force. On the other hand, by using a movable pulley, you only need to exert 5lbs. of force. With that, it’s time to go to the next method.

**Slide 21 –** A combination of fixed and movable pulleys, also known as the “block and tackle,” is the third method of using pulleys to achieve mechanical advantage. They provide more mechanical advantage than the other two and change the direction of the force. If there is a single rope of cable that is threaded multiple times through the system of pulleys, then the number of strands opposing the force of the load is the IMA. You do not count the strand you pull on. Now look at the image on the right, what is the mechanical advantage of this system of pulleys? (wait for their responses) If you said four, you are correct! If you look closely, you can count 4 strands that oppose the load. Now that that is done, it’s time to move on to the last simple machine.

**Slide 22 –** Last, but not least is the screw. You have probably seen the screw before in your life, whether it is your wall, in your desk, or your parents’ toolbox. The screw is a cylinder that has an inclined plane wrapped around it. The ridges around the shaft or cylinder are called the thread. The closer the threads, the greater the mechanical advantage. The distance between each thread is called the Pitch. The pitch may be the same for each screw of the same model, but different models on screws have different distances. This is done due to the variety of materials that screws are used for since certain pitch lengths work better for certain materials than others. Drills can be used to keep things together or lift objects. Adjustable stools used screws to allow you to adjust the height of the seat.

**Slide 23 –** The IMA of the screw is a little tricky. You need to first measure the radius of the screw and then find its pitch. When you have the radius, you then must multiply it by two and pi to get the circumference. Once you have that, you divide the circumference by the pitch to get the IMA. Alternatively, you may just find the diameter and multiply it by pi to get the circumference.

**Slide 24 –** Now that we are done with all this lecturing, it’s time to have some fun! Today we have a game for you to play that will allow you to learn about simple machines and conserving energy. Your job is to get Twitch across using simple machines. Some are more efficient than others, and your overall score will depend on how high your mechanical advantages are at each level. You will be given ten minutes to play the game, so make the most of it and get to the highest level you possibly can!

Associated Activities

**Finding Simple machines –** Students are given 10 minutes to find at least one example of a simple machine in their household and then present it to the rest of the students. The goal is to get students to identify simple machines in the real world and explain why they are examples of simple machines.

[**MA Quick Question Worksheet**](https://docs.google.com/document/d/19MR3em-sFIN9e8jyTu3thIBiHAfp81TcLgtZ2ZPXHbU/edit?usp=sharing) **–** This quick mechanical advantage question is intended to make sure that students are paying attention and applying what they learn. The question is very easy to avoid them from being worried or discouraged about it. It requires basic knowledge on how to manipulate fractions. There will be an explanation after for those who got it incorrect or didn’t understand it. It is also followed by a 5-minute break so that they can relax.

[**Museum of Science and Industry: Simple Machines Game**](https://www.msichicago.org/play/simplemachines/) **–** Students will be given 10 minutes (20 if they chose to continue playing the game well into the break time that follows) to play a virtual game courtesy of the Museum of Science and Industry Chicago that allows students to learn how to correctly solve simple challenges by applying the correct simple machine. The game also provides students with the mechanical advantage they got from using their chosen simple machine. The goal of the game is to get “Twitch,” a character in the game, across the obstacles they face in their little journey by using simple machines.

Lesson Closure

(Lesson closure begins right after the 10 minutes allotted for the game) Well, now that you all have an understanding of what mechanical engineering is, we expect that you will be able to not only identify simple machines present in your everyday life but also be able to use them more efficiently. Furthermore, we hope that you will be able to retain this information so that it can be applied again when the students go into an entry-level engineering course (Intro to Engineering Design as an example).

You all may continue playing the game if you like during the 10-minute break. We will go over automotive design in the next lesson just so you are all aware. Enjoy your 10-minute break!

Vocabulary/Definitions

***Mechanical engineering****: the branch of engineering dealing with the design, construction, and use of machines.*

***Simple machines****: A machine that has very little or no moving parts that make doing work easier. Examples are the wedge, lever, wheel and axle, screw, inclined plane, and pulley.*

***Mechanical Advantage****: The ratio of the output force from the machine to the input force initially applied to it. It is the advantage gained when using simple machines which decreases the effort needed to complete a task, making it easier.*

***Work****: Force applied on an object multiplied by the distance said object travel. W = F x d*

***Force****: A push or pull on an object*

***Archimedes****: A 3rd century BC Greek mathematician, engineer, and inventor.*

***Stonehenge****: A prehistoric monument located in Wiltshire, England, UK. It is made up of large standing stones in the form of a ring. It is assumed to have been founded in the Bronze Age.*

***Inclined plane****: a plane that is inclined at an angle to the horizontal that is used to raise an object to a greater height without the need for moving parts. An example is a ramp.*

***Lever****: A lever is simply a plank or rigid beam that is free to rotate on a pivot.*

***Pulley****: A grooved wheel in which a cord runs. It is used to change the direction of a force, oftentimes to lift something.*

***Wedge****: A Wedge is just two inclined planes joined back to back that are used to separate things.*

***Screw****: A simple machine that holds things together or lifts them. It is a cylinder with an inclined plane wrapped around the cylinder.*

***Wheel & Axle****: A simple machine in which an axle and a wheel are combined to reduce the friction of moving by rolling. The wheel is meant to turn the axle it is attached to, while the axle itself is a cylinder that supports the wheel or wheels attached to it.*

Assessment

**Pre-Lesson Assessment**

The pre-lesson assessment is a verbal assessment in which the presenter asks students if they have any prior knowledge about simple machines and to provide any examples. Based on the students’ responses, the presenter can either further simplify the lesson or speak to them at a higher grade-level.

**Post-Intro Assessment**

Have students take a picture of slide 4 of the [Simple Machines Presentation](https://docs.google.com/presentation/d/1U6ieo8bSQD_JhbiFr8agn9W8F768oAZ1KzGapO2nW_s/edit?usp=sharing) for future reference.

Additionally, there will be a quick question for them to answer on slide 7. That is the [MA Quick Question Worksheet](https://docs.google.com/document/d/19MR3em-sFIN9e8jyTu3thIBiHAfp81TcLgtZ2ZPXHbU/edit?usp=sharing).

**Lesson Summary Assessment**

Following the completion of the Mechanical Engineering Unit, students will be given an interactive quiz that will feature five questions about simple machines with multiple answer choices and one correct answer:

* How many simple machines are there? – 6
* What is a second-class lever? – Load is between the effort and fulcrum
* A rod attached to the center of a wheel is called… – An axle
* A screw is a(n) \_\_\_\_\_ wrapped around a central cylinder. – Inclined plane
* What simple machine would stairs be an example of? – Inclined plane

The “lesson summary assessment” will be this final quiz, which has 20 questions. The reasoning behind this was to avoid giving the students an exam after each lesson under the unit this lesson is a part of. The quiz itself is kept short so that students are not discouraged or intimidated by it. Additionally, students will be explained why the correct answer is correct and why the other answer choices are wrong after each question. This will allow the students to learn more and retain the information better. The quiz itself is also very interactive and visually appealing, which will keep the students engaged. Finally, each question is worth a certain amount of points, with students gaining points every time they get a question right. In the end, the top three students will receive a prize. The prize will provide the student with the incentive they need to do well on the quiz, but the quiz itself will be revealed at the end.

**Homework**

Students will be asked to find five simple machines in their home and write explanations describing what simple machine they are and why for each. They will turn it in the day after.

Lesson Extension Activities

Teachers may provide their examples of simple machines and use them while explaining each simple machine. Ideally, they may demonstrate a real-world example for each simple machine, including examples for each class of lever, and explain each of the examples according to the simple machine they represent.

Complex Machine Design: Have students design a complex machine with at least three of the six simple machines. Students would first need to choose the simple machines they wish to use. The students will then need to determine what the purpose of the machine is (i.e. what will it lift, pull, push, etc.). Next, they must design a complex machine that implements all their chosen simple machines. After designing the complex machine, the students must determine whether the complex machine will do its job efficiently. Once they have finalized their design, they will submit it to the teacher and receive feedback. They may be asked to redo it if it is not efficient (accompanied by an explanation as to why) or, if they did well, be asked what they did to make it efficient.

Additional Multimedia Support

The games used in the lesson will require the player to have Adobe Flash Player. If needed, guide the students through the installation process by visiting <https://get.adobe.com/flashplayer/>. Make sure they do not download McAfee Security Scan Plus and McAfee Safe Connect.

References

Dictionary.com. Lexico Publishing Group, LLC. Accessed July 22, 2020. (Source of some vocabulary definitions, most of which were done in my own words) <http://www.dictionary.com>

Live Science article on 6 Simple Machines: Making Work Easier Accessed July 22, 2020. (Source of some of my information regarding simple machines) <https://www.livescience.com/49106-simple-machines.html>

Teach Engineering Lesson: Engineering: Simple Machines Accessed July 20, 2020. (Used a basis for my lesson along with the source of some definitions which were altered along with the education standards) <https://www.teachengineering.org/lessons/view/cub_simple_lesson01>

Teach Engineering Lesson: Triangles & Trusses Accessed July 20, 2020. (I loosely based the structure of my lesson on this source, but no information was taken or needed from it) <https://www.teachengineering.org/lessons/view/cub_trusses_lesson01>

CPALMS Standards Accessed July 23, 2020 (Source of educational standards)<https://www.cpalms.org/Public/search/Standard>

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