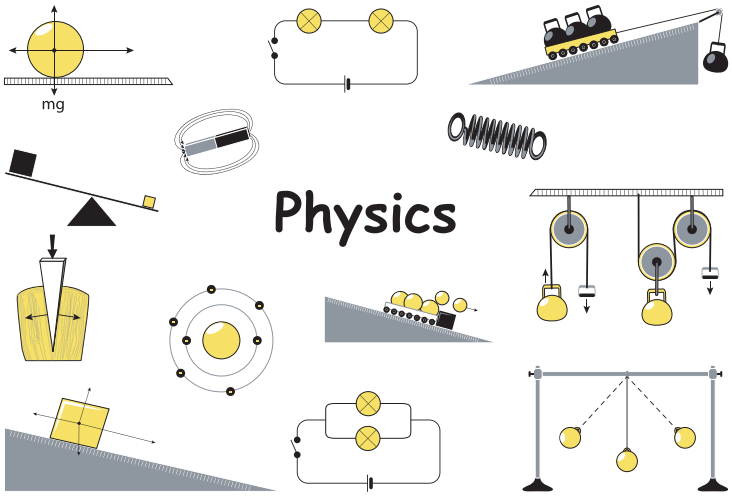
Simple Machines

SIMPLE MACHINES are the basic building blocks of all our tools and complex machines we use today. They are the foundation and basic means by which all tools and machines work. Simple machines use a mechanical advantage. This amplifies a force by altering your work from the required input to an increased output.



Objective:

Analyze the characteristics of mechanical advantage, and demonstrate the use of simple machines.

Key Terms:

actual mechanical advantage (AMA)
fulcrum
ideal mechanical advantage (IMA)
inclined plane
lever
mechanical advantage
pulley
screw
simple machine
tool
torque
wedge
wheel and axle
work

Characteristics of Mechanical Advantage

Simple machines are used to do work by changing the amount and direction of a force. A **simple machine** is a device that uses leverage to magnify force. Simply machines take one force and apply it to a load to perform work in their basic form. They increase the output force relative to the amount of input force. The ratio of the increase in a force is known as the machines mechanical advantage.

MECHANICAL ADVANTAGE

Mechanical advantage is a measure of the force amplification attained by the machine. **Work** (in physics) is a measure of energy transfer that occurs when an object is moved over a distance by an external force at least part of which is applied in the direction of the displacement.

Work is basically a force over a distance. This means there is a trade off with simple machines. Although there will be a decrease in required force to perform the work, it needs to be applied over a longer distance, or period of time.

There is an even exchange of energy, to perform the work or move something. You are applying a smaller force longer even though it may be easier to push or pull something with a simple machine.

ACTUAL MECHANICAL ADVANTAGE

The **actual mechanical advantage (AMA)** is the ratio of output to input forces. All machines transmit mechanical energy. The measure of its efficiency is the ratio of the output force (Fo) to the input force (Fi). This is the actual mechanical advantage.

The formula is: AMA = Fo/Fi. The higher the result the more useful the machine is. Some of the input force is used to overcome friction, and this is not typically known. This makes it difficult to get the actual mechanical advantage. So another formula can be used to get the ideal mechanical advantage.

IDEAL MECHANICAL ADVANTAGE

The **ideal mechanical advantage (IMA)** is the ratio of the input distance (Di) to the output distance (Do). The formula is: IMA = Di/Do. The input distance should be larger than the output distance if it is making work easier. Each type of simply machines has a slightly different variation of the formula for calculating the IMA.

FURTHER EXPLORATION...

ONLINE CONNECTION: Simple Machines, Pulleys

Pulleys use basic mechanical advantage to allow you to lift heavy loads that normally you could not lift. They use a basic set of principles and relationships that help convert and multiply your input force to an increased output force. Basic pulley machines or used in many machine systems.

To learn more about how pulleys work visit the web link below:

https://www.youtube.com/watch?v=BJ9MELhhW6U

Lever

The IMA for a lever is determined by the placement of the fulcrum. The **fulcrum** is the point on which a lever rests or is supported and on which it pivots. The fulcrum is located under the lever with two important distances. One is the distance it is from the input force (Di) and the other is the distance from the output force (Do). The formula is: IMA = Di/Do

Pulley

A pulley's mechanical advantage depends on the number of ropes. The number is represented by (N). The formula is: IMA = N.

Screw

A screw is basically an inclined plane that is circular. One turn of the screw rotates it at a distance equal to its circumference. The distance is called (P) and represents the amount of surface the screw has penetrated. The diameter of the screw shaft is (d). The formula is: IMA = 2 d/P.

Inclined Plane

An inclined plane's mechanical advantage is based on the height of its slope and the length of the plane. The mechanical advantage increases as the slope decreases but a longer distance is required to reach the top.

The height of the slop is (h), and the distance or length of the plane is (L). The formula is: IMA = L/h.

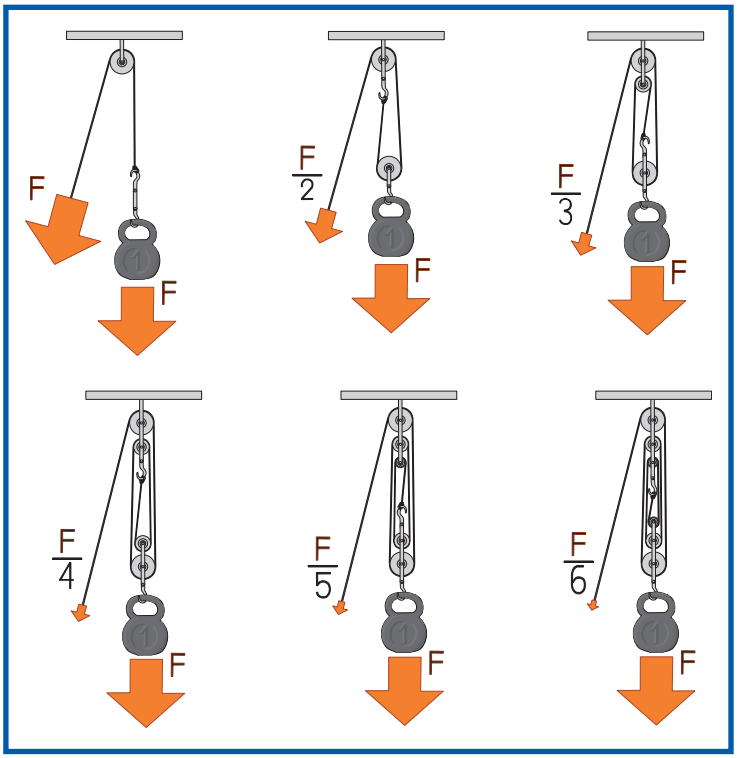


FIGURE 1. The advantage of a pulley system increases as you add ropes or pulleys. For each pulley you connect to the system you also add a rope lope. Each rope lope or additional pulley increases the systems mechanical advantage.

Wedge

A wedge is similar to an inclined plane. The force required to push it under a load increases as the slope of the wedge increases. A lower slope requires less force but needs a longer distance to separate a material to full height of the wedge.

The distance the wedge needs to go is (L). The height of the wedge or is (t). The formula is: IMA = L/t.

Wheel and Axle

A wheel and axle applies a force to a larger wheel while the smaller axle is connected to a load. The radius of the larger wheel is (R). The radius of the smaller axle is (r). The formula is: IMA = R/r.

The Use of Simple Machines

Simple machines are tools. A **tool** is an object used to extend the ability of an individual to modify features of the surrounding environment. Tools increase our ability to perform work, this maybe for refining materials, fabricating products, or processing information.

Most simple machines only have one moving part, some do not have any. Simple machines are put together with other simple machines and parts to create complex machines. There are hand tools and power tools. Hand tools use human generated energy and power tools use an external source of energy.

Most machines remain still during work or processing and rely on moving tools that are externally powered, for example, a drill press. A drill press uses a drill bit that is essentially a screw. It also uses a pulley to rotate the drill.The work is based on how it uses the wedge and inclined plane.

TYPES OF SIMPLE MACHINES

There are basically six different simple machines as noted in objective one. They can be divided into two categories. One that changes the force along vectors, such as a diagonal force divided along a horizontal and vertical. This would include the inclined plane, screw, and wedge. The second group includes those that rely on torque to alter force. **Torque** is a rotational force. Simple machines that rely on torque to alter force include the lever, pulley and the wheel and axle.

Inclined Plane

An **inclined plane** is a flat supporting surface tilted at an angle, with one end higher than the other, used as an aid for raising or lowering a load. One edge of the plane is at a different height than the other edge. It is one of the oldest simple machines and it does not need to move to perform its work. A basic form of the inclined plane is a ramp.

The mechanical advantage of an inclined plane is equal to the ratio between the distance over which input force is applied and the distance of output; or, more simply, the ratio of length to height. It requires less force to increase the height of something by spreading the work out over a distance, as with a ramp, than it does lifting it vertically straight up. A smaller force is needed; however it is performed over a longer period of time. There are many devices and compound machines based on the inclined plane.

FURTHER EXPLORATION...

ONLINE CONNECTION: How a Wedge Works

A simple wedge can make your work a lot easier and more efficient when used properly. The slope of the wedge in relation to its distance allows you to convert a force from one direction into another. This has significant advantage in terms of how your force and work is applied.

To learn more about how a wedge works visit the web link below:

https://www.youtube.com/watch?v=No5Df2231YA

Wedge

A **wedge** is a triangular shaped tool, and is a portable inclined plane. It is driven between two objects or parts of an object to secure or separate them. It is basically a double inclined plane that moves to perform work. When it moves forward it can transform the direction of its force into the directions that are perpendicular to its inclined surfaces.

Common examples of a wedge are a knife, an axe, or a chisel. It is essentially a triangular shaped tool that can separate or lift an object. By redirecting force it can also act as a stop or to hold an object, such as a door stop.

The ratio of the length of the two slopes to their heights is its mechanical advantage. For example, a short wedge with large slopes will be able to separate a material faster but will require more force. They are used to split wood, as valves in engine parts and bicycle brackets as well as the tip of a nail.

Screw

A **screw** is a mechanism that converts rotational motion to linear motion, and a torque to a linear force. It is essentially an inclined plane wrapped around an axis that can convert a torque. The screw is able to change rotational movement into linear movement, as the screw is turned or rotated (in a material) it will move up or down.

The inclined plane or groove of the screw transfers the rotational force to one that is perpendicular to its surface. The inclined plane or grooves of the screw are also called threads. The more threads there are over a given distance the lower the slope and the less force required to move it. However, the increase in threads leads to more distance that needs to be covered. This means a smaller force is required over a longer period of time.

This is referred to as the screws lead, or the distance it covers in one full rotation. It is also used to determine its mechanical advantage. A higher mechanical advantage will have a smaller lead. There are many uses for a screw, including a bolt or fastener, screw tops or rotational knobs, and propeller blades used in air and water.

Lever

A **lever** is composed of a rigid object that rest on a pivot or fulcrum. By applying one force along the rigid object the level is able to transfer and magnify the force to another location. A good example is a see-saw. It essentially relies on torque.

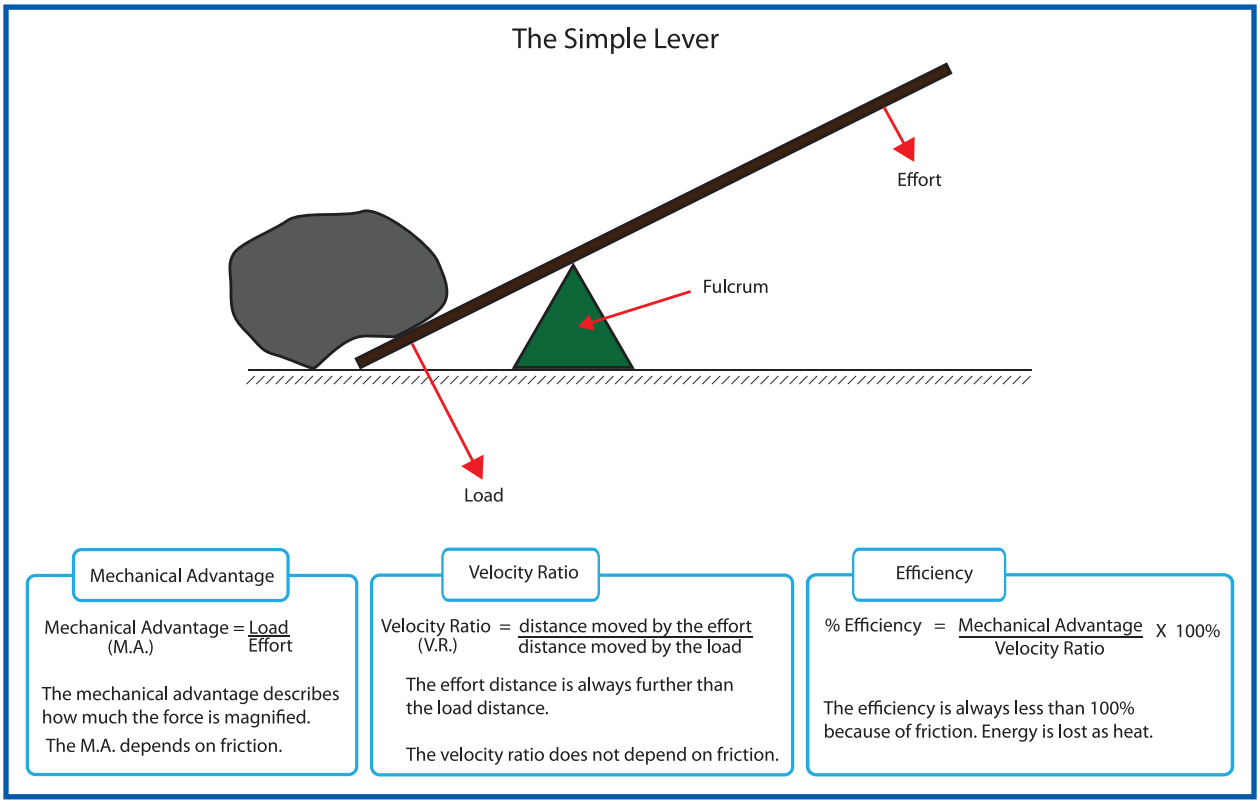


FIGURE 2. Levers are amazing simple machines. They use the basic concept of mechanical advantage to magnify the force required to lift heavy loads with a much smaller applied force. This is based on the distance the load is from the fulcrum to the distance of the applied force to lift it.

The amount of input force versus output force is determined by their distance from the rotation point at the fulcrum. The larger the distance is between the force and the fulcrum the greater its mechanical advantage. This distance translates into an increase in force on the other side of the fulcrum (or pivot point.) The longer the distance the force is spread out the more work it can perform.

If two people sat on a see-saw and where the same weight the one farther from the pivot point would create the larger force, lifting the other one up. A lever is one of the most common used simple machines, anything with a handle that does work essentially relies on a lever.

There are basically three types of levers. One type is where the force is on either end of the centralized pivot, such as a see saw. The second type is where the force is over the pivot, such as a wheel barrel. The third type is one the force is applied between the pivot and opposite end such as with tweezers. Other examples of levels include a baseball bat and crow bar. The longer the bar or bat the greater the force.

Wheel and Axle

A **wheel and axle** is a device that has a circular element which is attached to a rigid center bar. It is essentially a type or variation of a lever. In this case the lever can rotate completely around the fulcrum. The wheel and axle can magnify a force and convert rotational motion into linear motion.

Torque or the rotational force is a ratio relative to the axle radius and the radius to the outside of the wheel. This can also be called its mechanical advantage. When a force is applied to the wheel it will rotate the axle, this can be used to wind up a rope. The force can also be applied at the axle and then used to rotate the wheel such as an automobile tire. There are many examples of how a wheel and axle are used to magnify and convert forces; some include gears, bicycle wheels, lawn mowers, and rolling pins.

Pulley

A **pulley** is a wheel and axle system with a grove cut out of the outer edge of the wheel for a rope, cable or belt. Pulleys can convert the direction of an applied force and enhance it relative to their different diameters and number. They transmit rotational motion that can be realized in a rotational system for motion or into a linear system. They also use the principle of applying a smaller force over a longer distance to achieve a specific amount of work.

Pulleys can be organized into complex systems that can greatly reduce the amount of force required to move objects or perform work. A belt and pulley system will have more than one pulley and can be used to convert mechanical, rotational power, and torque to axles. They are used in machining and in automobiles. The different diameters of the pulleys can greatly increase the force.

There are both fixed and moveable pulley systems. They can be used in combination known as a compound pulley. A system with multiple pulleys and a rope is called a block and tackle.These systems also use tension to reduce the required force necessary for doing work. They can convert one direction of a linear force into another direction. The number of pulleys and the amount of tension will increase the mechanical advantage. However, the increase in pulleys creates many locations for friction and other ways of losing energy making the system less efficient.

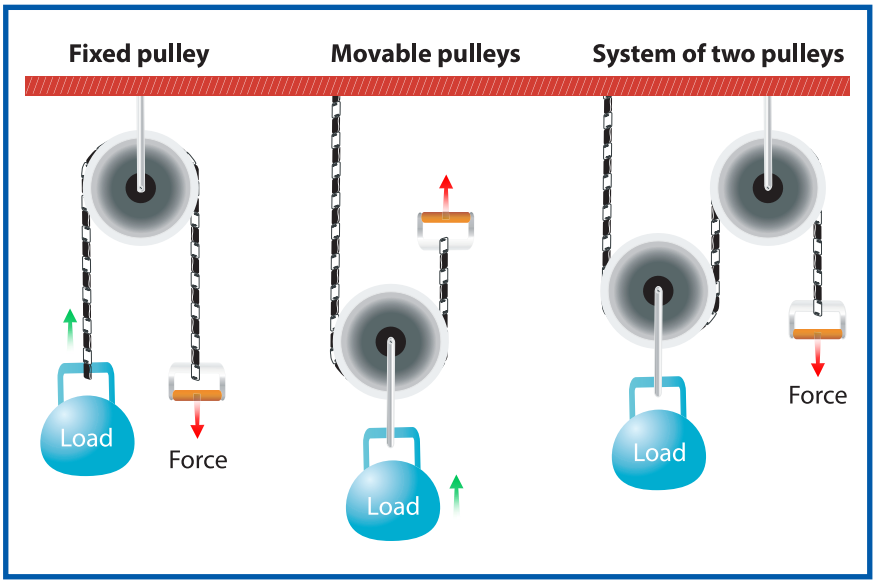


FIGURE 3. There are several different types of pulley systems that allow for a range of applications and specific needs to perform work functions.

Summary:

Simple machines are used to do work by changing the amount and direction of a force. A simple machine is a device that uses leverage to magnify force. Mechanical advantage is a measure of the force amplification attained by the machine. Work (in physics) is a measure of energy transfer that occurs when an object is moved over a distance by an external force at least part of which is applied in the direction of the displacement.

The actual mechanical advantage (AMA) is the ratio of output to input forces. The formula is: AMA = Fo/Fi. The ideal mechanical advantage (IMA) is the ratio of the input distance (Di) to the output distance (Do). The formula is: IMA = Di/Do. Each type of simply machine has a slightly different variation of the formula for calculating the IMA.

An inclined plane is a flat supporting surface tilted at an angle, with one end higher than the other, used as an aid for raising or lowering a load.

A wedge is a triangular shaped tool, and is a portable inclined plane. It is driven between two objects or parts of an object to secure or separate them.

A screw is a mechanism that converts rotational motion to linear motion, and a torque to a linear force.

A lever is composed of a rigid object that rest on a pivot or fulcrum. By applying one force along the rigid object the level is able to transfer and magnify the force to another location.

A wheel and axle is a device that has a circular element which is attached to a rigid center bar. It is essentially a type or variation of a lever.

A pulley is a wheel and axle system with a grove cut out of the outer edge of the wheel for a rope, cable or belt. Pulleys can convert the direction of an applied force and enhance it relative to their different diameters and number.

Checking Your Knowledge:

1. What machine converts rotational motion to linear motion, and a torque to a linear force?
2. How does an inclined plane work?
3. What is the difference between actual mechanical advantage and ideal mechanical advantage?
4. What is torque?
5. What simple machine device has a circular element that is attached to a rigid center bar?

Expanding Your Knowledge:

A great way to learn about simple machines is to experiment with them. You can use pulleys, a wedge or lever. You can adjust their amount, height, or length and see how much input force or effort is used to move an object. By applying the equations to your studies you can also see the ratios required to perform the work.

Web Links:

Simple Machine Facts
http://idahoptv.org/sciencetrek/topics/simple_machines/facts.cfm

Six Types of Simple Machines
https://www.vexrobotics.com/vexiq/education/iq-curriculum/simple-machines-and-motion/six-types-of-simple-machines

Six Simple Machines Making Work Easier
https://www.livescience.com/49106-simple-machines.html