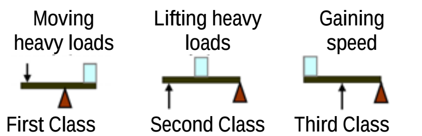
SIMPLE MACHINE - LEVER

Lever – is a rigid bar or plank that can rotate around a fixed point called a pivot, or **fulcrum**. Levers are used to reduce the force need to do a particular task**.**
The **fulcrum** supports the load. The force exerted on the lever to make it move is called the **effort force**. The mass of the object lifted by the lever is called the **load**.



The distance between the fulcrum and the effort force is called the **effort arm**. The distance between the fulcrum and the load is called the **load arm**.

SIMPLE MACHINE – WHEEL and AXLE

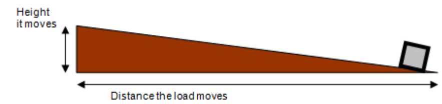
The **Wheel and Axle** is a combination of two wheels of different diameters that turn together - a lever that rotates in a circle around a center point or fulcrum.

A longer motion on the wheel produces a more powerful motion on the axle, thus giving it a **mechanical advantage**.

(Steering wheel in a car)

SIMPLE MACHINE – INCLINED PLANE

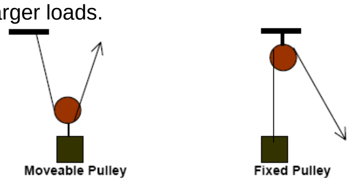
Inclined plane - or ramp, makes it easier to move a load higher than it is, but, it has to be moved over a much longer distance. An inclined plane makes it possible to lift heavy objects using a smaller force (examples: loading ramp, wheelchair access ramp)



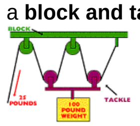
A **switchback** in the mountains is an application of how an inclined plane can be useful and practical.

SIMPLE MACHINE - PULLY

A **Pulley** consists of a wire, rope, or cable moving on a grooved wheel. One or more combinations of wheels and ropes can be fixed in place or moveable. Pulleys help you lift larger loads.



A complex combination of fixed and movable pulleys is called a **block and tackle**.

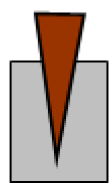


Depending on the number of pulleys used, a block and tackle can have a large mechanical advantage.

SIMPLE MACHINE - WEDGE

Wedge is similar in shape to an inclined plane, but is used in a different way (and can only be used in one direction). It is forced into an object to split it apart.

The wedge increases the force applied to the object, but it moves a greater distance into the object than it splits apart.

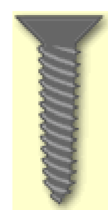


Examples: axe blade, a knife, a pin

SIMPLE MACHINE - SCREW

A **Screw** is a cylinder with a groove cut in a spiral on the outside. (It is actually an inclined plane that winds around itself) It helps you increase the force you use.

It can be used to convert rotational (turning) motion to linear motion (movement in a straight line). It moves objects in a straight line very slowly.



Examples: jar lids, light bulbs, and spiral staircases

COMPLEX MACHINE

Several simple machines all working together in a system are called **complex machines**.

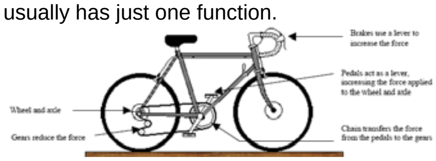
A **system** is a group of parts that work together to perform a function. A wheel and axle can be also be used to increase the speed (bicycle wheels) for a **speed advantage**.

As time passed, people expected more and more difficult tasks to be completed by machines. Machines became more complex. Power sources had to be developed to run these complicated machines.

Over the last two centuries - coal, oil and electricity powered complicated machines were developed to do work in large factories. The **industrial revolution** used these large complicated machines to mass-produce goods for use by consumers.

BICYCLE

The **bicycle** is a good example of a complex machine because it is a system for moving a person from one place to another. Within the bicycle are groups of parts that perform specific functions, such as braking or steering. These groups of parts are called **subsystems**. Each subsystem in a complex machine contains a simple machine and usually has just one function.



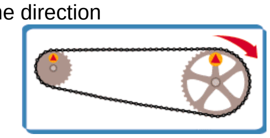
The subsystems of a bicycle are:

- Wheel and axle
- Drivers & Gears
- Frames & Materials
- Brakes & Steering
- Aerodynamic design

SUBSYSTEMS TRANSFER FORCE

The subsystems in a mechanical device play a role in how energy is transferred within the system.

A **linkage** is the part of the subsystem that transfers your energy from one part of the machine to another.. Chains or belts form a direct link between two wheels – one that drives the motion and the other will follow in the same direction



Machines that are more complex than a bicycle move much larger loads. A special type of linkage is needed. It is called a **transmission**. It transfers energy from the engine to the wheels.
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GEARS

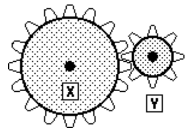
Gears are essential components of most mechanical systems. They consist of a pair of wheels that have teeth that interlink. As they rotate together, one gearwheel transfers turning motion and force to the other.

Gears can be used to change the direction of motion in a mechanical device, or to increase or decrease force or speed.

Gear wheels – which are wheels with precisely manufactured, identical teeth around its edge - work together transferring rotary motion and force from one part of a complex machine to another part in gear trains of two or more wheels.

A smaller gear (Y) is called a **pinion**. The gear that supplies the energy is called the **driving gear** (X). The gear to which the force is directed is called the **driven gear** (Y).

TYPES of GEARS



A ***large gear (X) driving a smaller gear (Y)*** decreases torque and **increases speed** in the driven gear. Gears such as these are called **multiplying gears**.

A ***small gear (Y) driving a larger gear (X)*** increases torque and **reduces speed** in the driven gear. Gears like these are called **reducing gears**. When the driving gear has fewer teeth than the driven gear, the driven gear then rotates more slowly than the driving gear. A car or bicycle in low gear uses reducing gears.

When the driving and the driven gears are the same size they are known as **parallel gears**.

MECHANICAL ADVANTAGE

A machine makes work easier for you by increasing the amount of force that you exert on an object. This produces a **mechanical advantage**, which is the amount of force that is multiplied by the machine. The force applied to the machine (by you) is the ***input force***. The force that is applied to the object (by the machine) is the ***output force***.

Mechanical Advantage is calculated as follows:

$$MA = \frac{\text{Output Force}}{\text{Input Force}}$$

Mechanical advantage is *force ratio*

$$MA = \frac{F_{Out}}{F_{In}}$$

The more a machine multiplies the force, the greater is the mechanical advantage of the machine

SPEED RATIO

Speed measures the distance an object travels in a given amount of time. The measure of how a machine affects speed is called the **speed ratio**. It is calculated by dividing the ***input distance*** by the ***output distance***.

$$SR = \frac{\text{Input distance}}{\text{Output distance}}$$

Speed Ratio formula:

$$SR = \frac{d_{in}}{d_{out}}$$

In a machine when you gain something, you also lose something. If you gain Force or Speed, you lose Distance. If you gain Distance, you lose Force or Speed.

FORCE of FRICTION

The difference between the calculated value and the real (actual) value of mechanical advantage is friction, which is **a force that opposes motion**. Friction is caused by the roughness of materials. Because friction is a force in any device, additional force must be applied to overcome the force of friction. The mechanical advantage of the device will be less because of this added force that must be overcome. The speed ratio will not be affected. In fact, the speed ratio represents the *ideal mechanical advantage* of a machine – as if friction didn't exist. Friction in a system also causes heat, which can cause additional concerns.

When people calculate mechanical advantage and speed ratio they may find that they are the same. In real situations however, when they are calculated, they are very different because of the force of friction.

EFFICIENCY

Efficiency is a measure of how well a machine or a device uses energy. The more energy that is lost, the less efficient a machine is. Efficiency is represented in %.

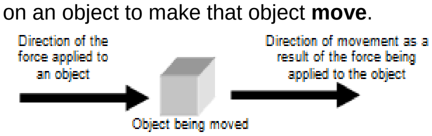
$$\text{EFFICIENCY} = \frac{\text{Mechanical Advantage}}{\text{Speed Ratio}}$$

In complex machines, there are many subsystems that are affected by friction and other factors. Because of this, most complex machines are not very efficient.

NO MACHINE CAN EVER BE 100% EFFICIENT

WORK

Scientifically, work is done when **a force** acts on an object to make that object **move**.



For work to be done there must be movement. If there is no movement, no matter how much force is used, no work is done.

Calculating Work
Work is calculated by multiplying the force times the distance the object moves. The formula looks like this:

$$W = F \times d$$

Force is measured in Newtons and distance is measured in meters. The resulting work unit is called a **joule**, named after the English scientist **James Joule.**

ENERGY and WORK

Energy and work are closely related, because without energy there would be no work. Work is done when there is a transfer of energy and movement occurs. Energy provides the force needed to make an object move. The energy can be in the form of human energy or it can be in the form of another energy source. A machine transfers energy from its source to the object, causing the object to move.

The work done with a machine is the same as the work done without it. This can be shown by calculating work input and work output.

$$Work_{input} = Force_{input} \times d_{input}$$

$$Work_{output} = Force_{output} \times d_{output}$$

The efficiency of the machine can then be calculated using this formula:

$$Efficiency = \frac{Work_{output}}{Work_{input}} \times 100$$

HYDRAULICS

Most machines that move very large, very heavy objects use a **hydraulic system** that applies force to levers, gears or pulleys. A hydraulic system uses a liquid under pressure to move loads. It is able to increase the mechanical advantage of the levers in the machine. Blaise Pascal discovered that pressure applied to an enclosed fluid is transmitted equally in all directions throughout the fluid, known as **Pascal's Law** making **hydraulic** (liquid) and **pneumatic** (air) systems possible.

Pressure is a measure of the amount of force applied to a given area.

$$p = F / A$$

p is pressure **F** is Force and **A** is Area

The unit of measurement for pressure is a Pascal (Pa), 1 **Pa**scal is equal to the force of 1 **N**ewton over an area of 1 **m**^{2}

HYDRAULIC SYSTEMS

In hydraulic systems, pressure is created using a piston. Pistons can be different sizes and hydraulic devices use pistons that are different sizes attached to each other with a flexible pipe. The Input piston is used to apply force to the fluid, which creates pressure in the fluid. The fluid transfers this pressure to the output piston. This pressure exerts a force on the output piston and the result is a mechanical advantage that makes the hydraulic system very useful.

The **mechanical advantage** in a hydraulic system comes from the fluid pressure in the system. Calculating the input force and the output force will give you the Mechanical advantage of the system.

MA = Output force / Input force

$$MA = F_o x d_o / F_i x d_i$$

PRESSURE and MECHANICAL ADVANTAGE

From Pascal's law, we know that the pressure the small piston creates is the same everywhere in the fluid. So the large piston has a larger area and is able to multiply the pressure because of its larger area. The force and area at each piston act as ratios that have to be equal.

$$\frac{\text{Force of the small piston}}{\text{Area of the small piston}} = \frac{\text{Force of the large piston}}{\text{Area of the large piston}}$$

$$\frac{F_{small}}{A_{small}} = \frac{F_{large}}{A_{large}}$$

By solving this ratio you will find that the forces created within a hydraulic system provides very large mechanical advantages - making them useful in many applications.

EVALUATION

Mechanical devices are constantly being evaluated to find ways they can be improved. The design and function of a mechanical device is related to its efficiency and effectiveness. What effect it has on the environment and how advancements in science through knowledge, trial and error can also help to stimulate change.
When a device has broken down or become ineffective in performing its function, making decisions as to what new device will replace the broken device have to be made with specific criteria in mind. The list of criteria you decide on will determine how well the replacement will meet your needs. The criteria might include:

- Use
- Purpose
- Cost
- Esthetics
- Workmanship
- Reputation

EVOLUTION

A machine can change and evolve over the course of many years. Change might be simple or complex depending on the evaluate criteria used to determine what needs to be improved. Improvements can make the device more convenient, cost effective, and efficient and can affect the people using it, as well as the environment. A history look at a simple device can show how trial and error can play a role in improving technology. Improvements usually don't happen by accident. Careful evaluation and creative designs to perform the function help make changes more effective and efficient. Questions about safety, convenience, environmental effect and recycling potential are all factors that contribute to improvements being made. What are you looking to improve upon in the device? This should be one of the first questions you should answer when evaluating a device.

EVOLUTION of the CAN OPENER

The pop can opener went through very distinct design changes. Each new design was the result of improving upon the previous design – which had a problem.

Can Opener Design	Advantages	Disadvantages
Iron Can **1810**	Kept things sealed	Had to be opened with a hammer and a chisel
Steel Can Late **1800's**	Opened with a **church key**  A simple lever	Needed to have a church key handy to open it
Aluminum Can **1958**	Can opened by wrapping the metal around a key the 'side-seamer' (1877) Lightweight	Sharp edges 
Removable Pull Tab **1963**	Ringed tab made it easy to open	Sometimes the ring detached from the tab and the can couldn't be opened It also caused a **litter** problem and a safety hazard – because of the sharp edges of the tab
Push Button Tabs Mid **1970's**	Litter problem was solved	Hard to push the small button open, consumers didn't like using cans with two buttons
Non-removable Pull Tab **1980** 	The **'ecology top'** – because the tab stayed attached to the can By wiggling it back and forth, it could be broken off	The ring would not puncture the tab, but would break off, but it is the best solution thus far

TECHNOLOGY and CHANGE

New materials and **new technologies**, human demands and environmental needs all contribute to the development of changes to current devices.

When failure occurs, **modifications** must also be made to ensure the device performs its intended function effectively, safely and efficiently.

Trial and error also can play a role in technological development. Early devices were usually operated by hand. Improvements to the device, by making it perform its task more easily, came as people tried to make the device perform more efficiently with less effort.

INVENTION leads to CHANGE

The invention of **electricity** has also contributed to improvements. Charles Coulomb first identified electric charges in the 1700's, but it took almost 100 years to make electricity widely available to major Canadian cities, and it took until the 1940's to make it available to most communities in Canada. As scientists and engineers learned more about this new energy source, they found ways to use it in new technologies, such as the **light bulb** and the **electron microscope**.

New technology can also develop from unrelated research. **MAGLEV** (Magnetic Levitation) trains operate on super-conductive magnets, powered by electricity. The technology for the MAGLEV resulted from physics experiments using particle accelerators which use large amounts of electricity to create powerful; magnetic and electric fields.

ENVIRONMENT

Since the early 1960's the environment has impacted technological development because people wanted to repair the negative impacts they had made on the environment.

New technologies (like *recycling*) were needed to prevent more damage.

Processing materials over and over or making them *biodegradable* would address some of the issues.

Other technologies (like *oil skimmers*) would help make environmental clean-up more effective and prevent further damage.

SOCIETY AND NEW TECHNOLOGY

Robots were originally popularized in movies and comic books. The word robot comes from the Czech word ***'robotnik'***, meaning workers, or slaves.

Robots today don't appear to be human-like, but they do the work of many humans, mostly in industry. The first practical robots were developed in the 1960's. Robots today weld car bodies together, diffuse bombs, perform surgery, help the handicapped and even explore other planets.

The drive to develop more effective and efficient robots came from the need to replace humans in the workplace. This was because humans were demanding more money for less hours of work and production costs were soaring. Industry decided to replace humans with robots – and most of these were just 'smart arms'.