1.0 – Machines are tools that help humans do work

1.1 – Simple Machines - Meeting Human Needs

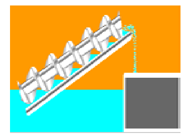
Machines help people use energy more efficiently. A machine helps us do work.

The earliest machines were simple devices to make work easier; like moving a large rock or moving a load up an incline, splitting wood or lifting materials up to a working area above the ground. These simple machines depended on people or animals as their source of energy.

Meeting the Same Need In Different Ways
Machines were built to satisfy basic human needs, such as getting water. Three devices used to get water in earlier times included:

Sakia (or, Persian wheel)

Roman aquaduct



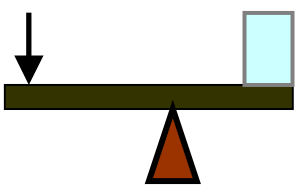
Achimedes screw

Simple Machines
A simple machine is a tool or device made up of one basic machine. There are six types of basic machines. http://www.fi.edu/qa97/spotlight3/spotlight3.html
http://www.usoe.k12.ut.us/curr/science/sciber00/8th/machines/sciber/intro.htm

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. You can move a very large load, but you must move a greater distance than the load moves.
http://207.10.97.102/elscizone/lessons/land/simplmachines/3classes.htm

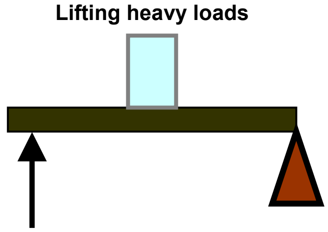
There are 3 classes of levers.  (a prybar can be all three classes of lever, depending on how it is used.)

Moving heavy loads



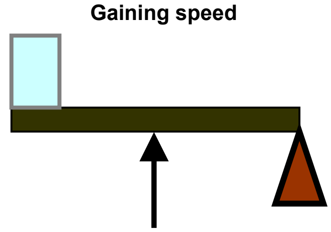
First Class Lever
crowbars and pliers

Lifting heavy loads



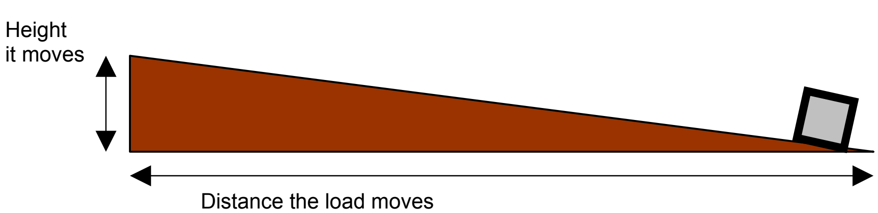
Second Class Lever
wheelbarrow

Gaining speed

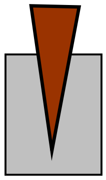


Third Class Lever
Hammer, your arm

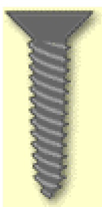
Inclined plane or ramp makes it easier to move a load higher than it is, but it has to be moved over a much longer distance. An inclined plane makes it possible to lift heavy objects using a smaller force (examples: loading ramp, wheelchair access ramp)



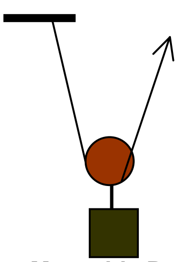
Wedge is similar in shape to an inclined plane, but is used in a different way (and can only be used in one direction). It is forced into an object to split it apart. The wedge increases the force applied to the object, but it moves a greater distance into the object than it splits apart.

Examples:
axe blade  or, a knife

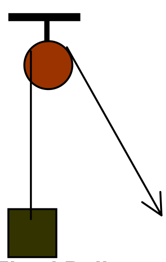
A **Screw** is a cylinder with a groove cut in a spiral on the outside. (It is actually an inclined plane that winds around itself) It helps you increase the force you use. It can be used to convert rotational (turning) motion to linear motion (movement in a straight line). It moves objects in a straight line very slowly.

Examples include: jar lids, light bulbs, and spiral staircases

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.



Moveable Pulley



Fixed Pulley

The **Wheel and Axle** is a combination of to 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. They can be used to increase the size of the force (steering wheel in a car) or the speed (bicycle wheels).

The Effects of Simple Machines

Change the direction of a force (a pulley on a flagpole)

Multiply force (a screwdriver)

Increasing or decreasing speed (scissors)

Transferring force (removing staples)

See also the review notes here: http://www.connect.ab.ca/~lburns/students_eightunit2notes.html

1.2 The Complex Machine – A Mechanical Team

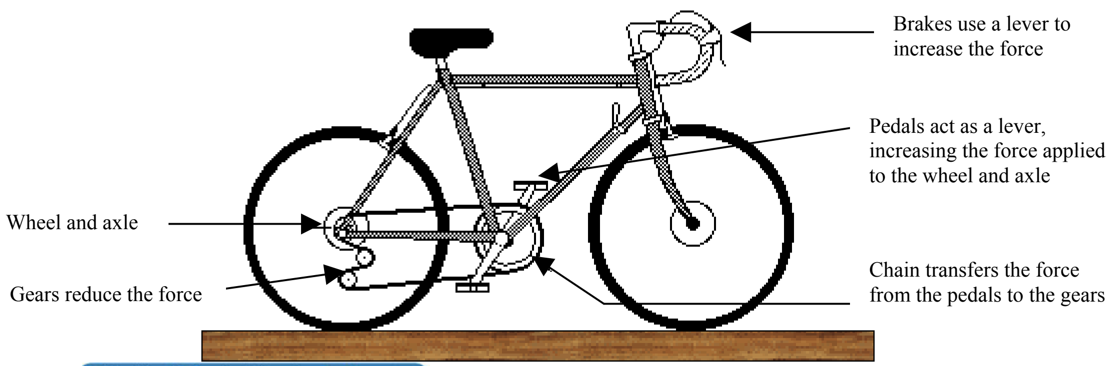
As time passed, people expected more and more difficult tasks to be completed by machines. Machines became more complex. Power sources had to be developed to run these complicated machines. Over the last two centuries - coal, oil and electricity powered complicated machines were developed to do work in large factories. The industrial revolution used these large complicated machines to mass-produce goods for use by consumers.

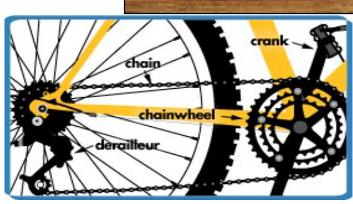
The **steam engine** moved these good across countries in a very short time, giving people more and better access to food, clothing, tools and raw materials than previously. The standard of living had improved. The continual development of new technologies has lead to our virtual dependence on machines.

Complex Machines

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.

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

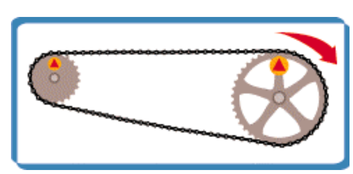
Explore the Science of Cycling at this website: http://www.exploratorium.edu/cycling/index.html
Build your Dream Bicycle: http://www.thetech.org/exhibits/online/topics/54j.html

Subsystems That Transfer Forces

The subsystems in a mechanical device that produce motion, such as in a bicycle, play a role in how energy is transferred within the system. The subsystems are called **linkages** and **transmissions**.

Linkages

The linkage is the part of the subsystem that transfers your energy from the pedals to the back wheel. In the bicycle, the chain is the linkage. In a car, the fan belt is the linkage from the engine to the cooling fan – to prevent the engine from overheating. Chains or belts form a direct link between two wheels – one that drives the motion and the other will follow in the same direction.



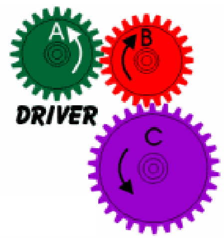
Transmissions

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. A transmission contains a number of different gears. This enables the operator to move the object slowly with a large force, or quickly with a smaller force.

Gears

Gears are essential components of most mechanical systems. They consist of a pair of wheels that have teeth that interlink. When they rotate together, one gearwheel transfers turning motion and force to the other.
There are many different types of gears. This website has just a few:
http://www.fi.edu/time/Journey/Time/Escapements/geartypes.html

. Gears can also be used to change the direction of motion in a mechanical device, such as in an ***eggbeater.***

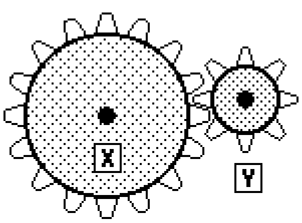


Gears can be used to increase or decrease force or speed

How Gears Work

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

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).



How Gears Affect Speed

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**.

2.0 – An understanding of mechanical advantage and work helps in determining the efficiency of machines

2.1 –Machines Make Work Easier

Machines help people do things that they normally couldn't do on their own.

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***.

Calculating Mechanical Advantage
The mechanical advantage of a machine is the output force divided by the input force.

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

The mechanical advantage is the *force ratio* of a machine.

$$\text{MA} = \frac{F_{output}}{F_{input}}$$

$\mathbf{F}$ = Force in Newtons (**N**)

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***.

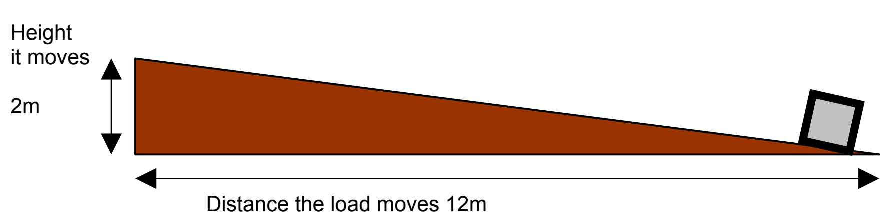
$$\text{SR} = \frac{\text{Input distance}}{\text{Output distance}}$$

$$\text{SR} = \frac{d_{input}}{d_{output}}$$

$\mathbf{d}$ = distance (**m**)

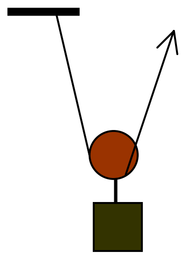
Using the formula provided, you can calculate the speed ratio of any device.

Less Force But Greater Distance
You do not get something for nothing when using a machine. The *advantage* to **gaining force** is offset by the *disadvantage* of **losing distance**.
An inclined plane makes it possible to lift heavy objects using a smaller force (examples: loading ramp, wheelchair access ramp), but you have to move the object over a much longer distance.

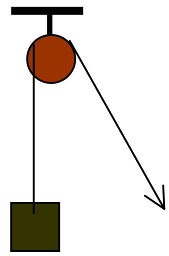


Mechanical Systems

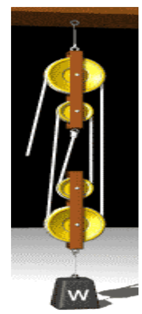
A **Pulley system** consists of one or more combinations of wheels and ropes, which can be fixed in place or movable. Pulleys help you lift larger loads. To calculate the **MA** of a pulley, count the number of ropes/cables **supporting the load**.



A single movable pulley
MA = **2**



A single fixed pulley
MA = **1**



Pulley System
MA = **4**

Pulley System
MA = **3**

A Mechanical Advantage Less Than 1
In the case of machines where the mechanical advantage is greater than 1 the machine is multiplying the input force to create a larger output force. If a machine has a mechanical advantage that is **less than 1**, it is useful for tasks that don't require a large output force. A bicycle is a machine with a mechanical advantage of less than 1. Even though it has a mechanical advantage of less than 1, the output force causes the bicycle to move faster than the rider could walk, so it is a very useful machine.

Comparing Real Mechanical Advantage With Speed Ratio
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 can be very different. This is because of friction.

The Effect 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.

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 represent in %.

$$\textbf{Efficiency} = \frac{\textbf{Mechanical Advantage}}{\textbf{Speed Ratio}} \times \textbf{100}$$

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.

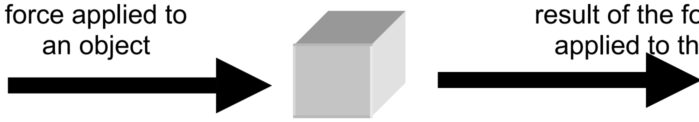
NO MACHINE CAN BE 100% EFFICIENT !!!!

2.2 The Science of Work

The Meaning of Work

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

In order to say that work is being done, there must be movement. If there is no movement, no matter how much force is used, no work is done.



For example; a worker uses force to move a large carton up a ramp. Energy (pushing) is transferred to the carton from the worker. Thus, we say that the worker did work on the carton as long as the carton moved up the ramp as a result of the worker's pushing action (force).

Calculating Work

The amount of work is calculated by multiplying the force times the distance the object moves.

The formula looks like this: $\mathbf{W = F \times d}$

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 (muscle power – chemical reactions in the body producing energy) or it can be in the form of another energy source, such as gasoline (for a car). A machine transfers energy from its source to the object, causing the object to move. There is a very complicated chain of events that make a car move - beginning with it being fueled up with gasoline - all the way through its many subsystems (each doing work) - to eventually the tires rotating to make the car move forward or backward.

Work and Machines

There are different types of simple machines that can help us do work. 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 is the work needed to use, or operate the machine

$$\text{Work}_{\text{input}} = \text{Force}_{\text{input}} \times d_{\text{input}}$$

Work output is the work done by the machine.

$$\text{Work}_{\text{output}} = \text{Force}_{\text{output}} \times d_{\text{output}}$$

Work and Friction

Friction is the reason that work input does not equal work output in real situations. Friction affects the machine's efficiency. Efficiency can be calculated using work input and work output.

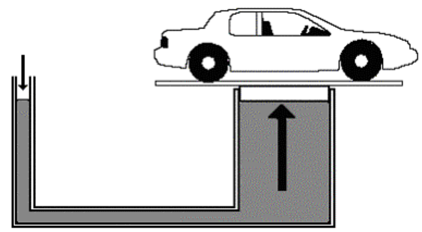
$$\textbf{Efficiency} = \frac{\textbf{Work}_{\text{output}}}{\textbf{Work}_{\text{input}}} \times 100$$

2.3 The Big Movers – 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.

Modern construction projects use hydraulic equipment because the work can be done quicker and safer. There are many practical applications of hydraulic systems that perform tasks, which makes work much easier.

A **hydraulic lift** is used to move a car above the ground, so a mechanic can work underneath it.



Pressure in Fluids

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), named after Blaise Pascal who did important research on fluids.

1 **Pa**scal is equal to the force of 1 **N**ewton over an area of 1 **m**^{2}

Pascal discovered that pressure applied to an enclosed fluid is transmitted equally in all directions throughout the fluid. This is known as **Pascal's Law** and it makes **hydraulic** (liquid) and **pneumatic** (air) systems possible. A common application of Pascal's law is illustrated above, with the hydraulic jack.

A Piston Creates Pressure

In hydraulic systems, the 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.

Mechanical Advantage In Hydraulic Systems

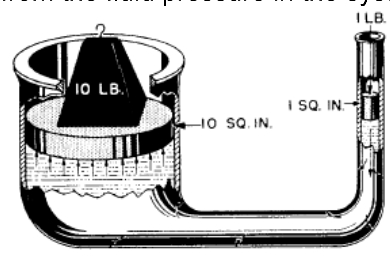
The mechanical advantage in a hydraulic system comes from the fluid pressure in the system.

Calculating the input force and the output force will give you the Mechanical advantage of the system.

MA = Output force / Input force

$MA = F_o x d_o / F_i x d_i$

MA = 10 / 1 = 10



This hydraulic system has a mechanical advantage of 10

Mechanical advantages in hydraulic systems are usually quite high, showing how useful they are.

Pressure and Mechanical Advantage

The reason for the large mechanical advantage in a hydraulic system is the ability of the fluid to transmit pressure equally. It allows you to use a small force on the small piston to produce a larger force on the large piston.

$$p = F / A$$

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.

Larger Force – Greater Distance To Move

Mechanical advantage in hydraulic systems has a cost. That cost is the increased distance the smaller force must go through to make the large force move a small distance.

To increase the force on the output piston ,
the input piston must move through a greater distance.

Amusement park rides make extensive use of hydraulic systems

3.0 – Science, society, and the environment are all important in the development of mechanical devices and other technologies.

3.1 –Evaluating Mechanical Devices

Mechanical devices have evolved over time because of science and the development of new technologies. 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. Mechanical devices are constantly being evaluated to find ways they can be improved.

Using Criteria To Evaluate A Device

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

Efficiency and Effectiveness

Mechanical devices are designed to work efficiently, which can be calculated by, dividing its mechanical advantage and by its speed ratio. This is a **quantitative measure** of efficiency, because it gives you a number or quantity of how efficient the device is.

Efficiency can also be described in **qualitative** terms. In other words, words can describe how quickly or easily the device performs the task it is designed for. It is efficient, if it does the task well enough to meet your needs.

Efficiency and effectiveness can be compared when analyzing the designs of different devices that do the same task (such as the bicycle). Usually you are looking for the best combination of efficiency and effectiveness at a cost you can afford.

Function and Design

Scientists, engineers and inventors want to develop mechanical devices that work the best for the work they are designed to do. The function is the purpose and the design is the form. The design should suit the function.

Evaluation For Development

Another reason for evaluating a device is to determine how it can be improved. The environment can have an impact on the design of a device as well. The development of mountain terrain bicycles came as a result of how the bicycle would best function in the rough terrain it would be used in.

Considering The Environment

The effect of a device on the environment should also be considered in evaluating it. The negative impact on the environment should not outweigh the usefulness or effectiveness of the device.

Evaluating A Mechanical Device – A Case Study

The pop can opener has changed over the years and these changes can help to explain how evaluation can lead to improvement. The improvements can make the device more convenient and can affect the people using it as well as the environment. The history of this device show how trial and error can play a role in improving technology.

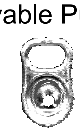
The pop can opener went through four distinct designs:

- The church key
- The removable tab
- The buttons
- The non-removable tab

Each new design was the result of improving upon the previous design – which had a problem.

Evolution Of A Mechanical Device – The Pop Can Opener

To pour a liquid out of any container, you need two holes or one large hole. With two holes, the first hole allows air into the can, the second hole lets the liquid flow out.

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

Criteria For Evaluation

The changes to the pop can didn't happen by accident. Careful evaluation and improved designs to perform the function help make the can opening changes more effective and efficient. Questions about safety, convenience, environmental effect and recycling potential were all factors that contributed to improvements being made. What are you looking for in the device? is one of the first questions you should answer when evaluating a device.

3.2 Technology Develops Through Change

New materials and technology, human 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 and efficiently. Trail and error also can play a role in technology 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. The invention of electricity also contributed to improvements.

Advances In Science Result In New Technology

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.

From Particles To Trains

New technology can also develop from unrelated research. The **MAGLEV** (Magnetic Levitation) trains in Japan operate on super-conductive magnets, powered by electricity. They can travel at speeds over 350 km/h floating on the rails. The technology for the MAGLEV resulted from physics experiments using particle accelerators (huge machines used to break apart atoms and other particles of matter) which use large mounts of electricity to create powerful; magnetic and electric fields.

Changes In Society Result In New Technology

New technology can also result from changes to human society. Robots were originally popularized in movies and comic books. The word robot comes from the Czech word ***'robotnik'***, meaning workers, or slaves. They were thought to be 'human-like' machines that could do the work of humans. It was originally used in a play where millions were manufactured to work as slaves in factories. Most robots today don't really 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.

Changing Society – Changing Technology

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'.

The Anatomy of a Robot This website will give you a comprehensive look at robots past and present. http://www.bbc.co.uk/science/robots/index.shtml

Robots have 6 basic components:
A Body, Motor devices, Power Source, Sensors, Output devices and Microprocessors. (p. 318)

Changes In The Environment Result In New Technology

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.