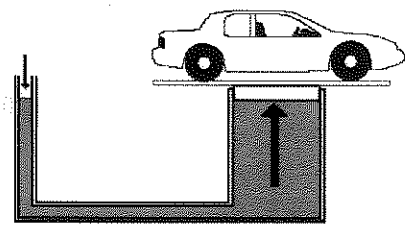
2.3 The Big Movers – Hydraulics

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 $\mathbf{m^2}$

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

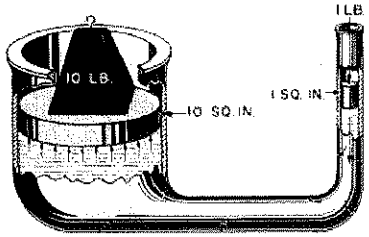
The mechanical advantage in a hydraulic system comes from the fluid pressure in the system.

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.

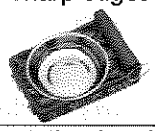
The pop can opener went through four distinct designs:

- 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.