Science Eight

Unit Four:

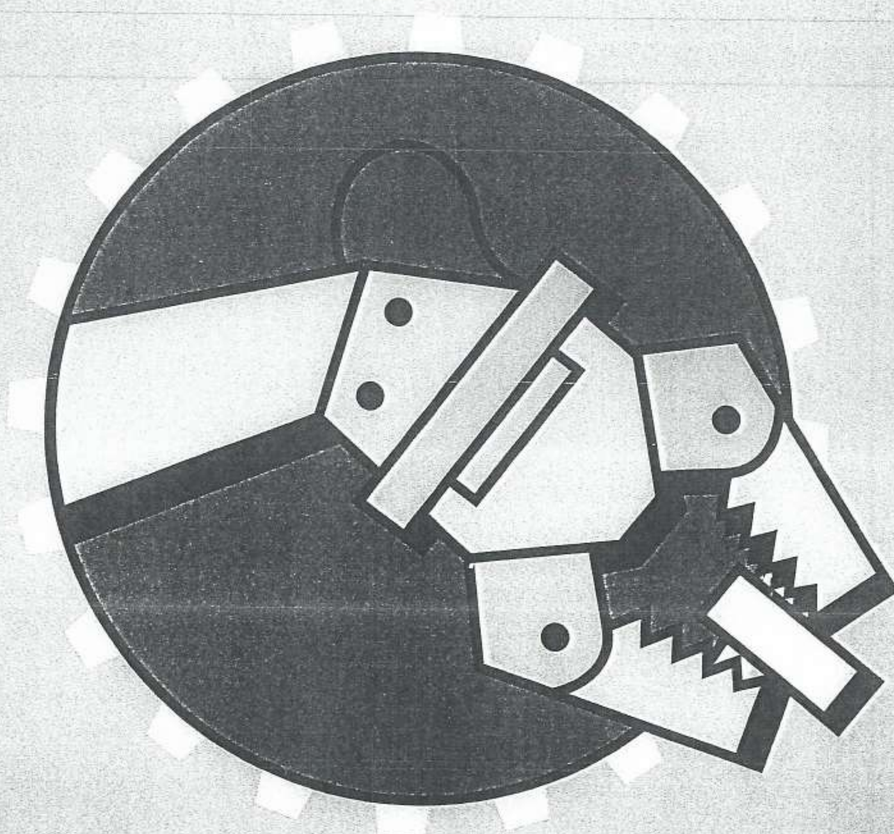
Mechanical Systems

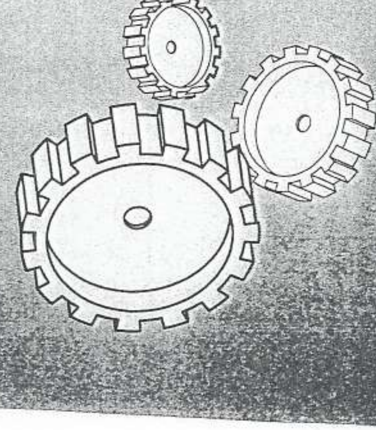
Name:

Date Received:

Date In:

MECHANICAL SYSTEMS





GRADE 8
TOPIC FOUR

NAME

Lacombe Outreach School

Part A: What is a mechanical device?

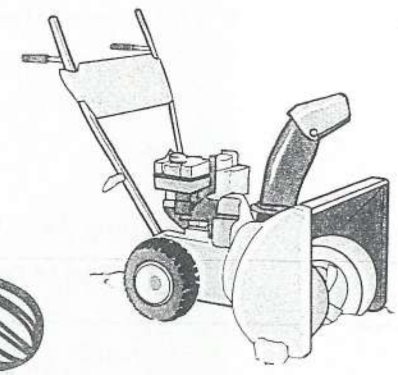
Mechanical Device

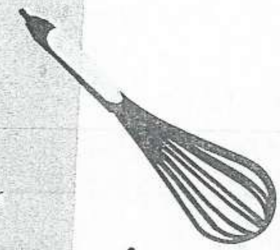
"Mechanical device" is the scientific word for "machine."

Machines are things that humans have created or built to help them do work and make jobs easier.

Simple machines are tools that use energy but make work easier. These tools usually have few or no moving parts.

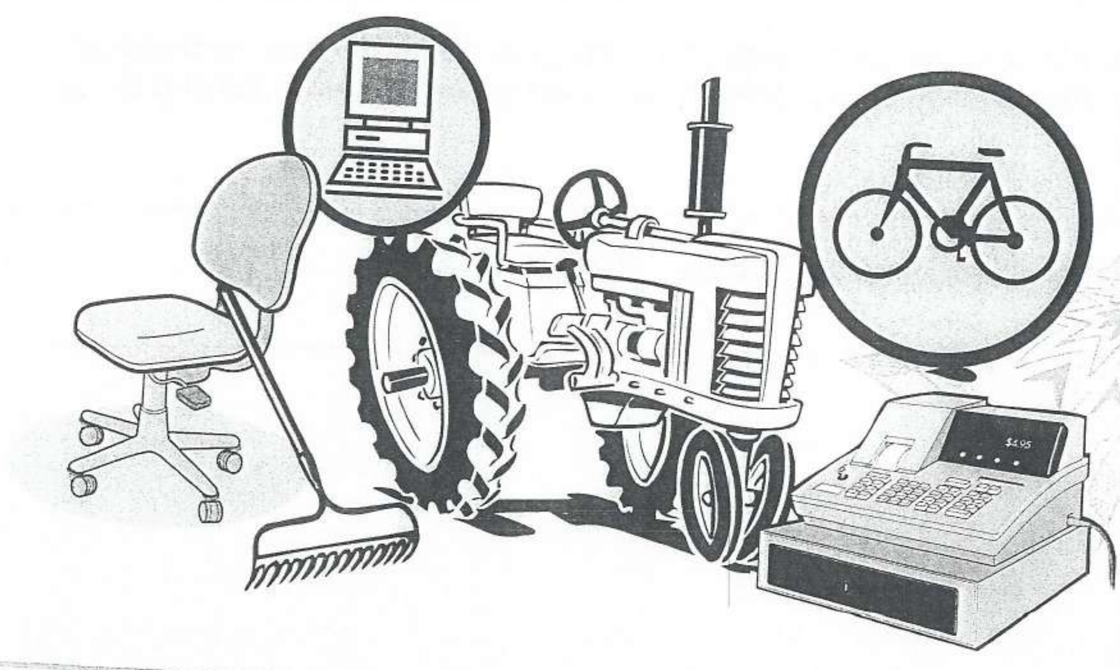
Complex machines are made up of two or more interconnected simple machines working together.





1. Put a check mark beside the six machines below.

a.	____	Rake	b.	____	Tractor
c.	____	Blanket	d.	____	Computer
e.	____	Chair	f.	____	Can opener
g.	____	Book	h.	____	House
i.	____	Cash register	j.	____	Bike



The Language of Machines

Interconnected:	Parts joined together to make a machine or part of a machine.
Components:	The parts of a machine.
Force:	The power or strength of the energy that a machine uses or produces.
Magnitude of Force:	The amount of force used or produced by a machine.
Direction of Force:	The way in which energy goes or moves into or out of a machine.
Transmit Energy:	When a machine sends, passes on, or spreads energy from one place to another.
Modify Energy:	When a machine changes the amount or type of energy.

Hint: For some examples, there may be more than one correct answer.

Explain which definition(s) best matches each of the examples below.

1. An egg beater has two sets of blades, a turning wheel and a handle.

   ____

2. A pair of scissors has two blades that are held together by a fulcrum in the middle.

   ____

3. An electric can opener changes the energy of electricity into mechanical energy (the energy of movement) as it turns a can around against a sharp edge.

   ____

4. A hammer drives a nail into a piece of wood.

   ____

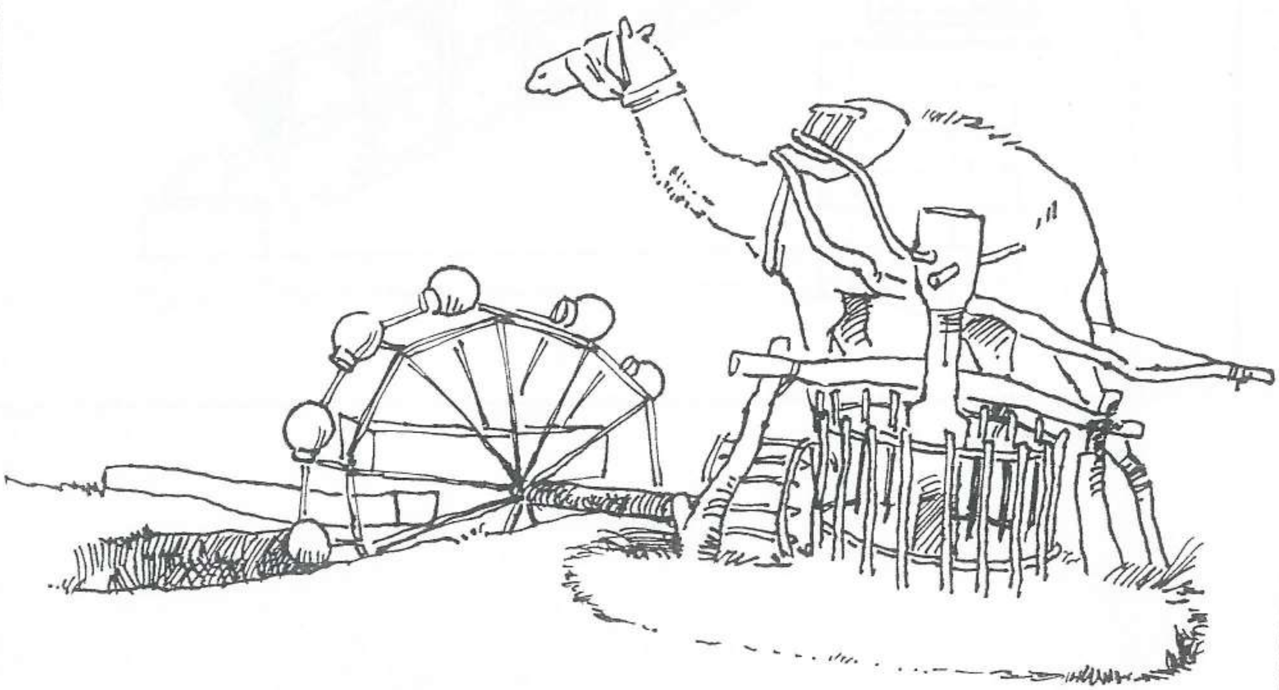
Part B: How have mechanical devices been used to supply people's water?

As you know, water is one of our most basic needs. It is necessary for our survival. The following devices were used in the past to help communities get the water they needed.

Persian Wheel

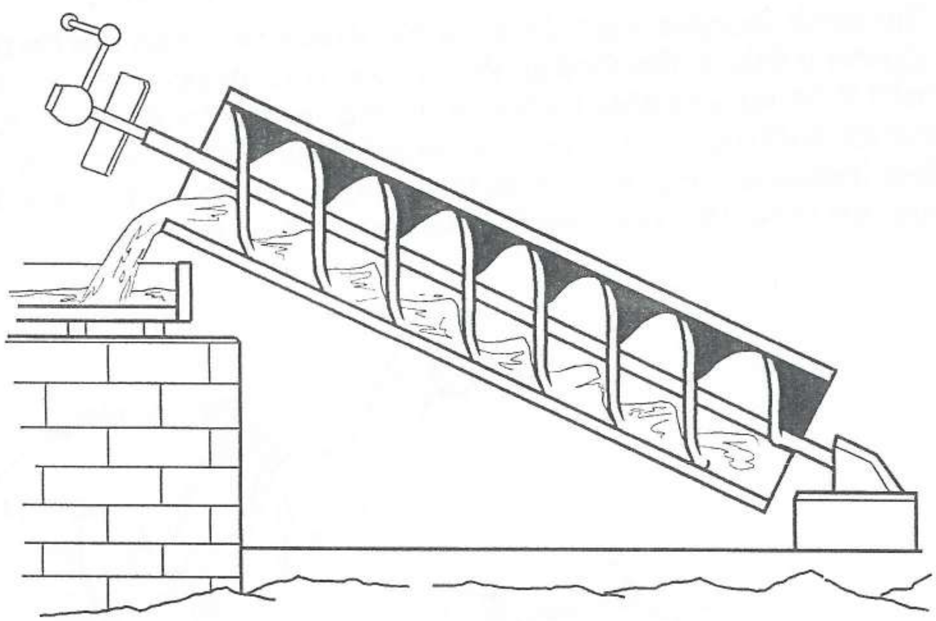
Before pumps were invented, gravity (the Earth's force that pulls everything downwards) was used to make water travel to where it was needed. The only problem was, the water had to be up high before it could flow down with the force of gravity. People created large tanks (containers) that were kept high above the community and then water would be let out of the tanks to flow down through pipes to where it was needed.

To fill the tanks, people used a mechanical device called the **Persian Wheel** (also called a *sakia*). The Persian Wheel had a long rope with buckets tied around it that would collect water from the source (well, river, etc.) and lift it up. Animals such as cows or camels were harnessed to the wheel and used to move it around and around. In this way, the large tanks were filled with the buckets of water collected by the Persian Wheel.



Archimedes Screw

In later times, Archimedes (a Greek scientist and mathematician) invented a faster, easier and more reliable way to move water. The mechanical device he invented was made of a long tube with a large screw inside. One end of the tube would be put under the water and the other end would be placed in a container to collect the water. Since water will always flow from an area where there is a lot to where there is less, the end of the tube in the water would automatically begin to fill with water. The grooves (lines cut into the sides) of the screw would fill with water and, as the screw was turned, the water would be pushed around and around up the grooves to the top of the screw. In this way, water would be pushed through the tube and out into the storage container.



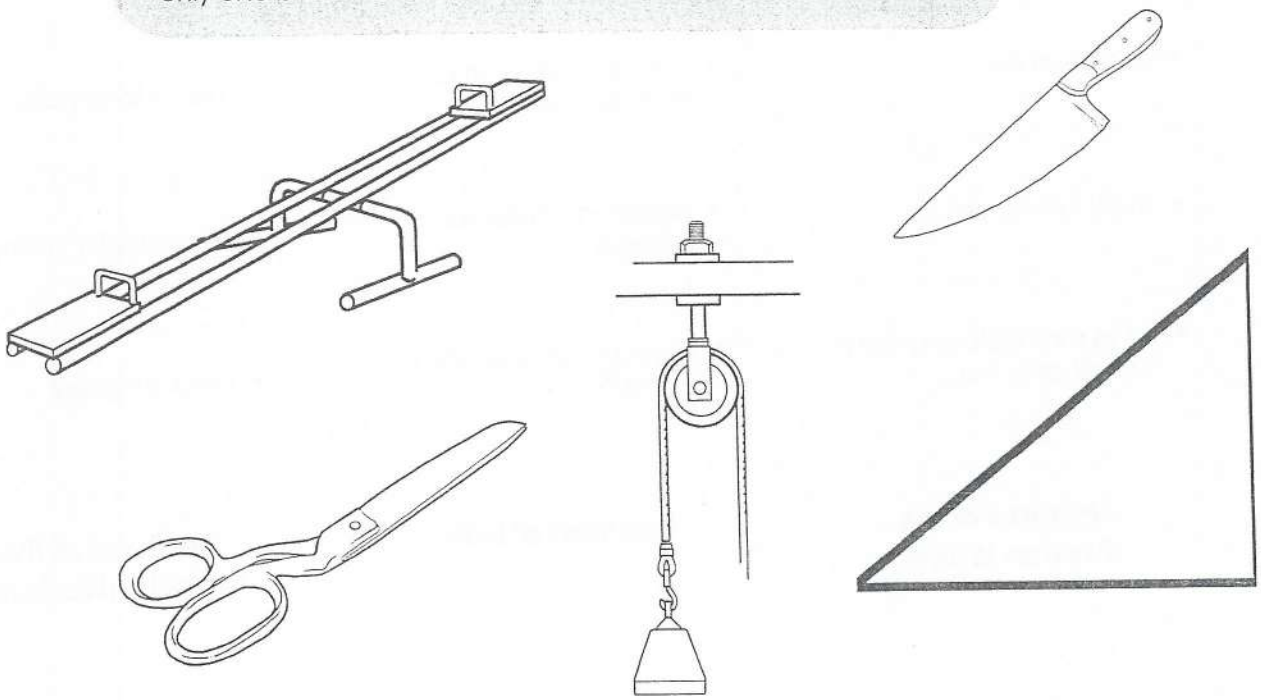
Sort and recopy the following information into the chart below to show how the Persian Wheel and the Archimedes Screw had similarities and differences.

• parts move in a circular motion	• works against gravity to lift water up	• moves water most efficiently
• uses buckets	• uses a piece of metal with grooves	• uses a long rope
• mechanical device	• transports water for storage	• powered by animals
• is the step before gravity is used as a tool	• supplied people with a necessity	• used long ago

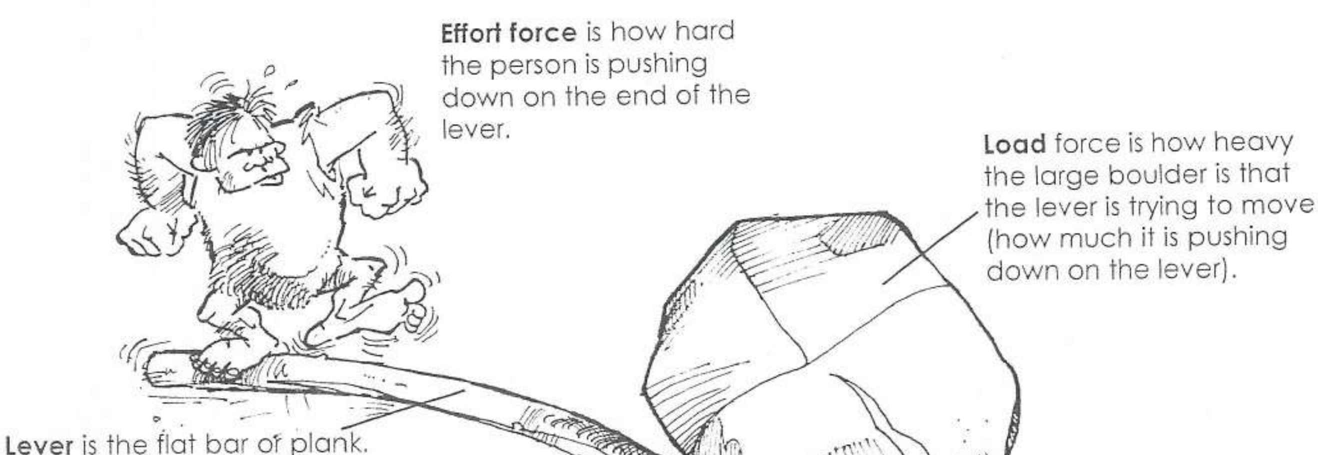
Features of the Persian Wheel	Features of both	Features of the Archimedes Screw

Part C: What are simple machines?

Simple Machine
A simple machine is any tool or device that is made up of only one basic machine.

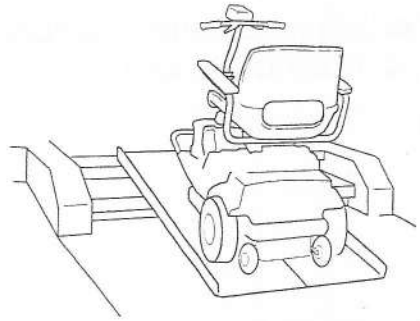


Lever
Levers have been used since early times. A lever is a flat bar or plank that can move over a fixed point. Levers are used to magnify (make bigger) the amount of effort a person needs to use to do things like pulling out nails, opening bottles and cutting paper.



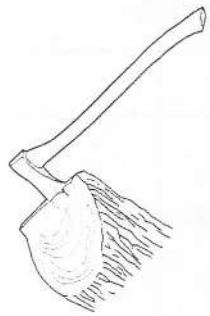
Inclined Plane

An inclined plane is also called a "ramp." A ramp makes it easier to move objects by sliding or rolling them slowly up or down instead of lifting them straight up or down.



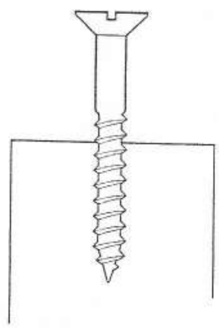
Wedge

A wedge is the same shape as a ramp but it is used in a different way. The thin edge of the wedge is put in position on an object and then the object begins to spread apart as the wider part of the wedge gets pushed into it.



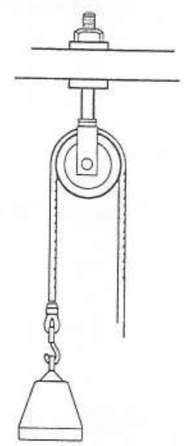
Screw

A screw is a cylinder (long tube-shaped piece) that has a long groove cut in a spiral running around and around it. You learned earlier that screws can be used to transport water, but they can also be used to push into wood more easily and the grooves "grab on" to hold it in place.



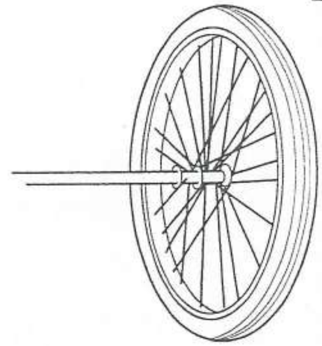
Pulley

A pulley is made of a wire, rope or cable that moves along a groove in a wheel. Pulleys are used to lift things. The heavier the load, the more pulleys are put together to do the job.



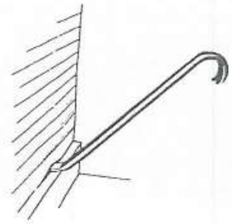
Wheel and Axle

A wheel and axle is made up of two different-sized wheels (round objects) that turn together. The bigger wheel takes a longer time to turn, but it pushes the smaller wheel around much faster. In this way, less force needs to be used to turn whatever is attached to the smaller wheel.

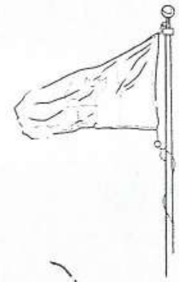


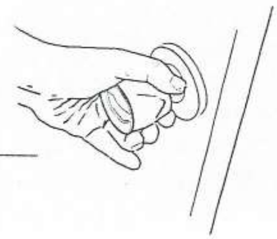
Decide which kind of simple machine is used to do work in each of the following mechanical devices.

1. Crowbar ____________________

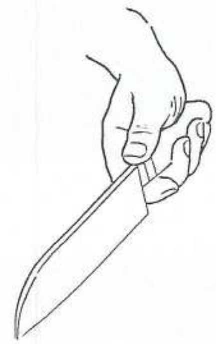


2. Flag Pole ____________________

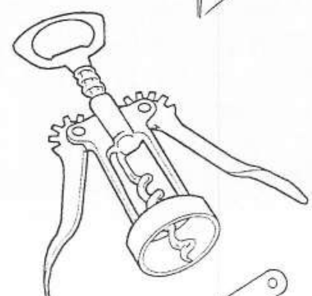




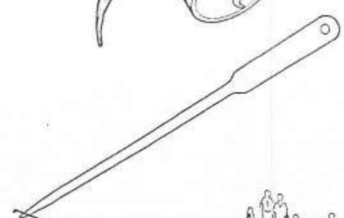
3. Doorknob ____________________



4. Knife ____________________



5. Corkscrew ____________________



6. Staple Remover ____________________

7. Escalator ____________________

8. Spade ____________________

9. Which of the simple machines can be used to help people to lift heavy objects?

10. How do machines help people do work?

11. If a machine already exists that can be used to do a job, why would people bother to invent another one?

12. Describe a simple machine that you use (or see used) on a daily basis. Explain how it works and how it makes it easier to do a task.

13. Imagine you are trying to get a couch from a moving van up to a fifth-floor apartment. How many different ways (using simple machines) can you think of to get the couch to where it needs to be?

Part D: How does trial and error learning play a role in the invention of mechanical devices?

Trial and Error

Trial and error is a term used to describe a way of finding out the best way to do something. It's trying one or more ways and learning not to repeat the same mistakes but build on the things that worked well. In other words, keep trying different things until one works!

The Aircraft—A Product of Trial and Error Design

Some of the earliest plans for making machines of flight were created by Leonardo Da Vinci. Many people used his ideas as a springboard to create plans and models of their own. Time after time, crafts were built and tested; some bounced along the ground, others rose into the air for a short time before crashing. Most models of flight were based on the study of birds. It was just a matter of creating something that worked like a bird, which was difficult because you can't see what is happening inside a bird as it flies. It was also difficult to understand the challenges of moving through the air (wind currents) because up until then, man lived firmly on the ground. Eventually, after many changes to plans based on mistakes made along the way, the Wright brothers were finally able to build a craft that would fly.

Considering how the airplane was created through trial and error, it would be easy to imagine that a submarine was the product of similar trial and error work. Explain why this is likely true, using evidence similar to that described for the airplane.

____

____

____

____

____

____

____

Optional: Research the invention of the submarine and see if your predictions were close!

Part E: How do complex machines work?

Complex Machine

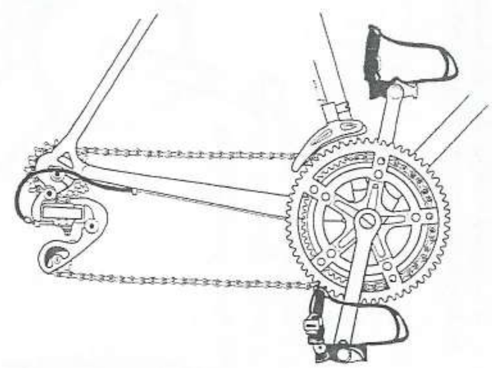
A complex machine is a mechanical device that is made up of a number of different simple machines working together.

System

The whole complex machine—all the parts working together.

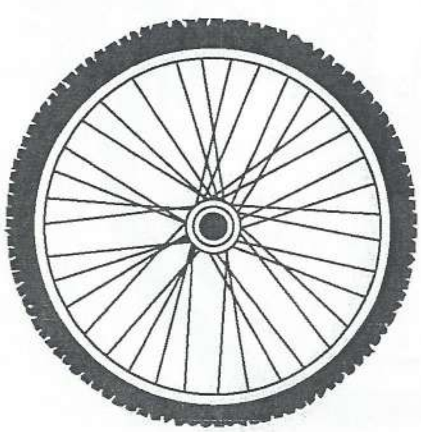
Subsystem

A part of the whole machine that includes certain parts working together to do a certain job. Subsystems working together make up the whole system.



Components

The individual parts (usually simple machines) that make up subsystems.



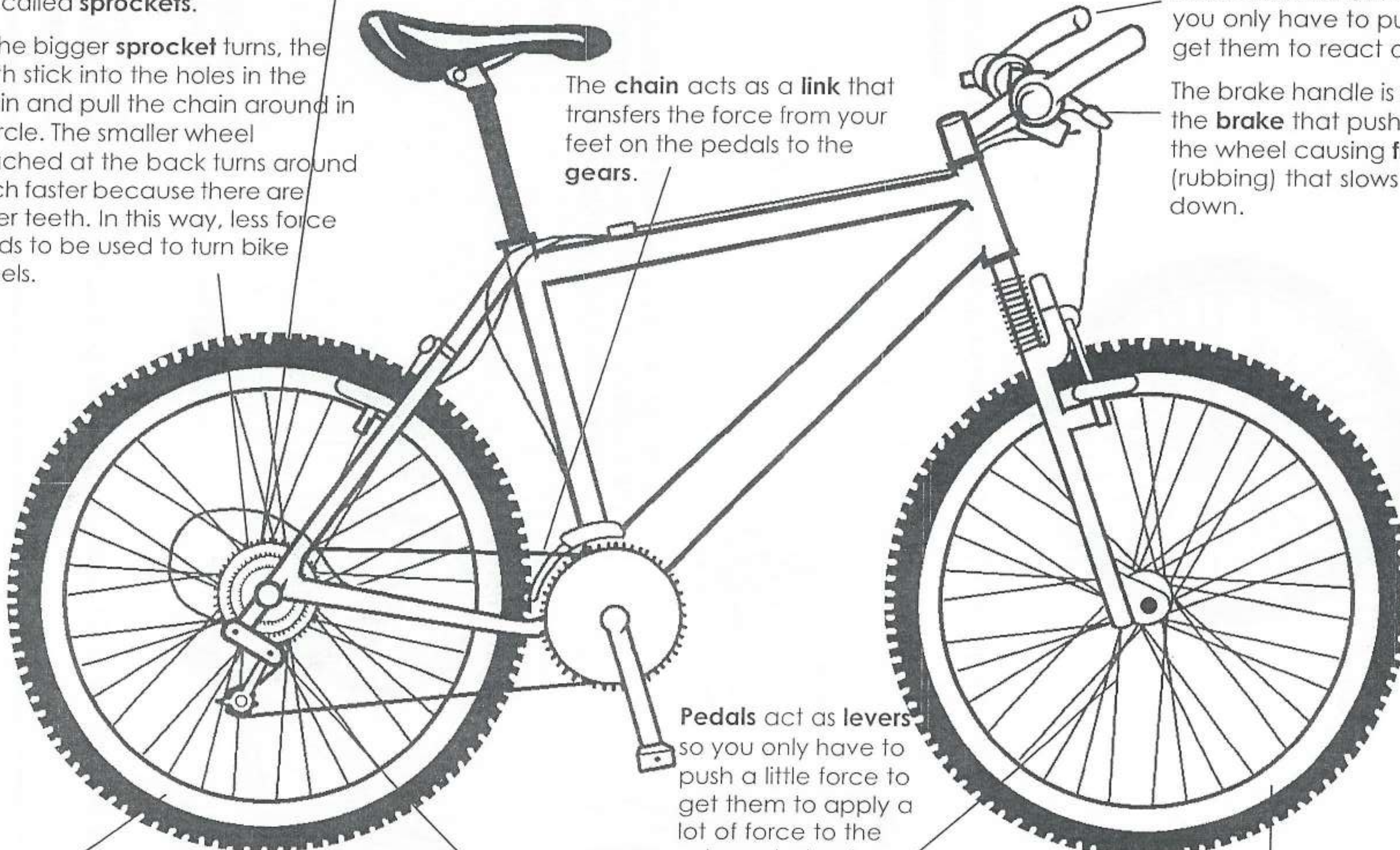
Gears are circles of different sizes that have teeth all around the outside edge. When gears are **linked** together by a chain, they are called **sprockets.**

As the bigger **sprocket** turns, the teeth stick into the holes in the chain and pull the chain around in a circle. The smaller wheel attached at the back turns around much faster because there are fewer teeth. In this way, less force needs to be used to turn bike wheels.

The **chain** acts as a **link** that transfers the force from your feet on the pedals to the **gears**.

Brake handles act as **levers** so you only have to push a little to get them to react a lot.

The brake handle is attached to the **brake** that pushes against the wheel causing **friction** (rubbing) that slows the bike down.



Pedals act as **levers** so you only have to push a little force to get them to apply a lot of force to the axle and wheel.

The **back wheel** powers the bike because the small, fast-moving **sprocket** is attached to the axle that is attached to the wheel.

Wheels have **axles** (cylinders) running through them so the **force** from the pedal makes the axle move quickly and the wheel it is attached to rolls in its large circle.

The **front wheel** moves because it is being pushed from behind, and wheels are always ready to roll.

1. What makes a bike move?

2. What makes a bike slow down?

3. What is the source of energy that starts a bike moving?

4. Which parts of a bike work together as a subsystem? How?

5. What is one of the component parts of a bike?

6. What is the most surprising thing you learned about how a bike works?

Part F: What are gears and how do they work?

Gear

A gear is an object that looks like a wheel with teeth around the rim (outside edge).

Gear Train

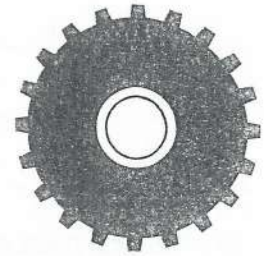
A gear train is when two or more gears are used together. When gears work together, the teeth of the first gear fit in between the teeth of the other gear, so when one turns, both turn.

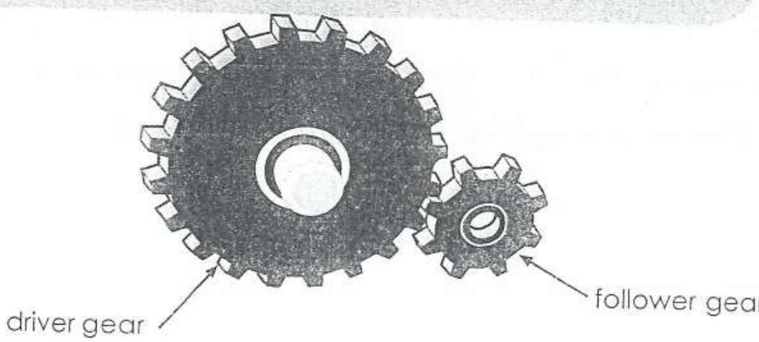
Driver Gear

The driver gear is the gear that is in front of a gear train. The driver gear turns because it is attached to a handle or a motor.

Follower Gear

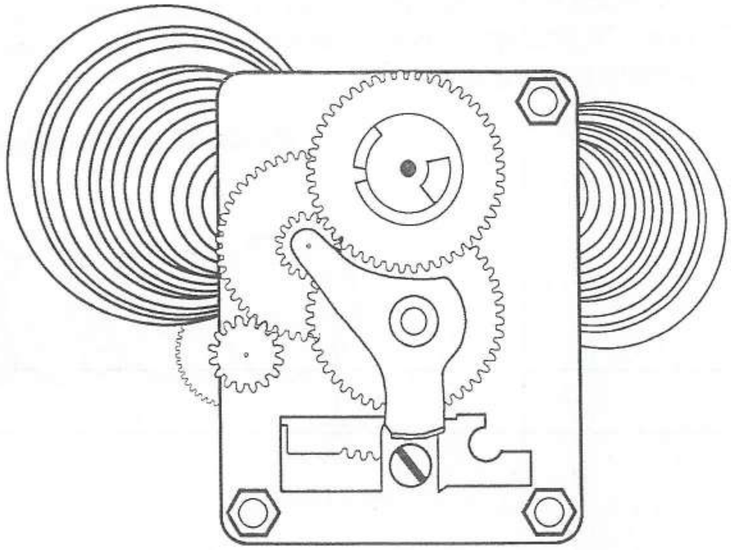
The follower gear comes after the driver gear. The follower gear moves because the driver gear is moving and the teeth of the two gears "mesh" together.





Use the information above to help you fill in the blanks in the passage below.

A gear is shaped like a _ _ _ _ _ (1) and has _ _ _ _ _ (2) around the _ _ _ _ (3). When two or more _ _ _ _ _ (4) work together in a _ _ _ _ _ _ _ _ _ (5), the _ _ _ _ _ (6) of the different gears _ _ _ _ (7) together. The front gear in a _ _ _ _ _ _ _ _ _ (8) is called the _ _ _ _ _ _ (9) gear and the next gears are called _ _ _ _ _ _ _ _ (10) gears. The _ _ _ _ _ _ (11) gear usually moves because it is attached to a _ _ _ _ _ _ (12) or a _ _ _ _ _ (13). The _ _ _ _ _ _ _ _ (14) gears move because the _ _ _ _ _ (15) of the gears _ _ _ _ (16) together and when the _ _ _ _ _ _ (17) gear moves the other gears do too.



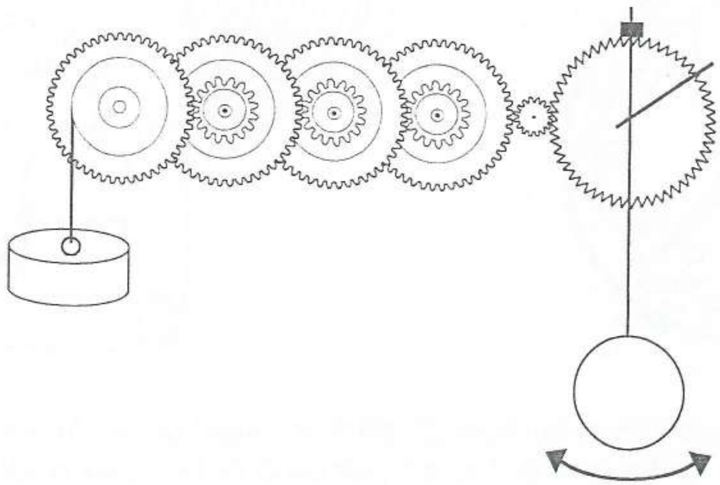
The inside of a clock has a number of different-sized gears. There is usually one driver gear connected to the power source (wind-up or battery) and then a follower gear for the hour hand, a follower gear for the minute hand and a follower gear for the second hand. As you know, the second hand moves the fastest, then the minute hand and the slowest is the hour hand. Think back to what you first learned about gears on bikes and answer the question below.

The inside of a clock has three follower gears: one large, one medium and one small. Which gear do you think likely runs (moves) each of the different clock hands? Explain how you know.

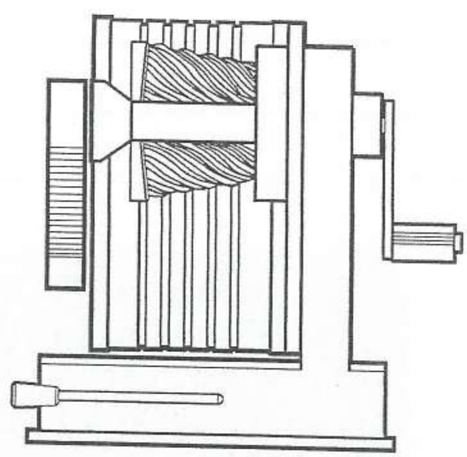
Gears often work together inside machines to connect different parts to the source of energy that starts the movement (e.g., a turning handle or a motor). As you learned about bikes, when gears are linked together by a chain, they are called sprockets. When gears are directly linked together, they are often called a wheel and pinion system (the wheel being the driver and the pinion being the follower).

Analyze each of the diagrams below and label parts that you recognize as gears, gear trains, sprockets, wheel and pinion systems, driver gears, follower gears, and simple machines.

Inside of a Grandfather Clock



Bicycle



Inside of a Pencil Sharpener

Part G: What are mechanical advantage, speed ratio and efficiency?

Work and Force

The scientific meaning of work is that work happens when a force acts on an object to make it move. Without movement, it is not considered to be work.

Work = Force x Distance

Work input is how much work is put into the machine and **work output** is how much work is done by the machine.

How to calculate Work Input and Output

Work *input* = F *input* x d *input*

Work input is calculated by multiplying the input force used by the distance moved.

Work output is calculated by multiplying the force output (created) and the distance output.

Work *output* = F *output* x d *output*

Note: Work is measured in Joules.

How to calculate Efficiency (Total Work)

Total work is calculated by dividing the work output by the work input (how much energy was used compared to the distance moved).

$$\text{Efficiency} = \frac{\text{Work } output}{\text{Work } input} \text{ X } 100$$

Calculate **work input**, **work output**, and **efficiency**:.

1. Input Force: 3N
   Output Force: 6N
   Input Distance: 12m
   Output Distance: 4m

   Work Input: ________
   Work Output: ________
   Efficiency: ________

2. Input Force: 8N
   Output Force: 16N
   Input Distance: 18m
   Output Distance: 3m

   Work Input: ________
   Work Output: ________
   Efficiency: ________

3. Input Force: 1N
   Output Force: 1N
   Input Distance: 10m
   Output Distance: 5m

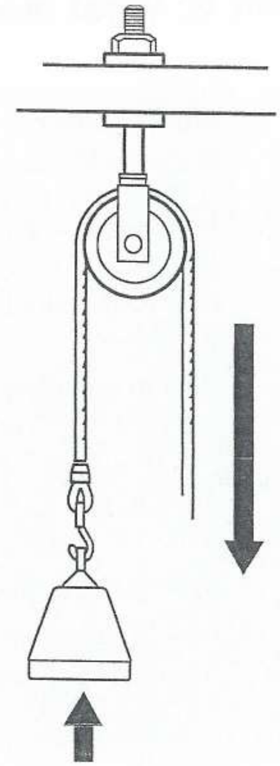
   Work Input: ________
   Work Output: ________
   Efficiency: ________

Mechanical Advantage

Mechanical advantage is how much more power or force you get by using a machine. Machines "multiply" force.

E.g., You can lift more weight using a pulley system.

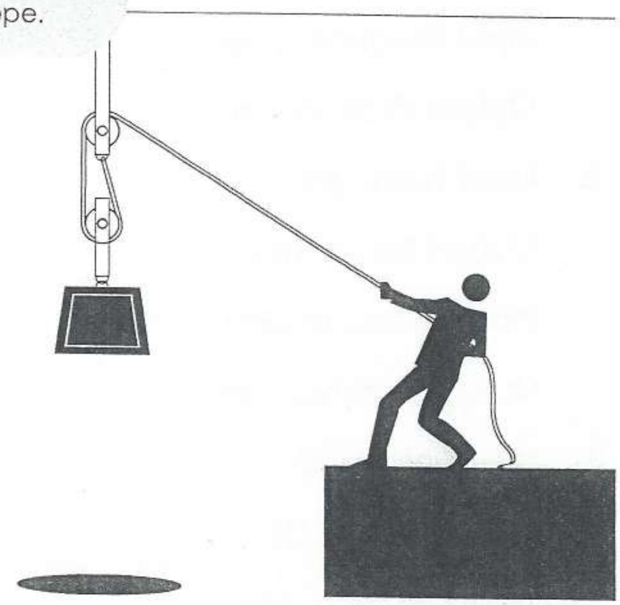
Note: How a machine is made and how many gears and pulleys there are, determines how much mechanical advantage it gives you.



Input Force

Input force is how much force (or power) you put into a machine.

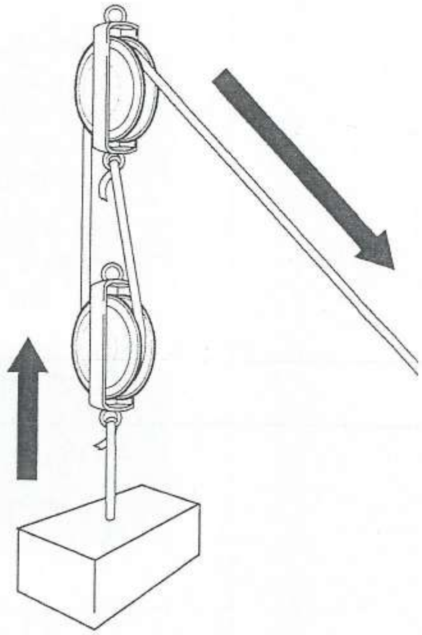
E.g., The power or force of you pulling on the rope.



Output Force

Output force is how much force (or power) the machine puts out in the end.

E.g., The force with which the weight is lifted.



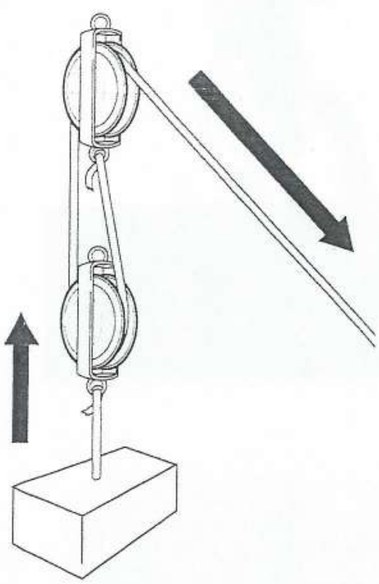
How to calculate Mechanical Advantage

Mechanical advantage can be calculated by **dividing** the total **output force** by the total **input force.** Remember, both force amounts must be in the **same units.**

Note: Force is usually measured in Newtons (N).

$$MA = \frac{F\ output}{F\ input}$$

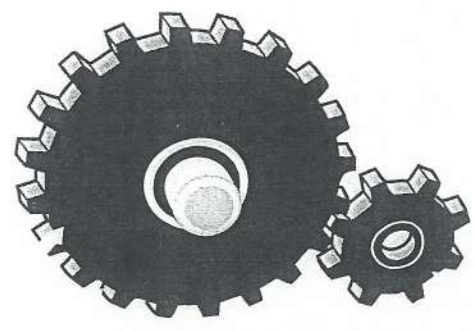
1. Calculate the mechanical advantage of the following mechanical devices:



Output Force = 8N

Input Force = 4N

Mechanical Advantage =



Output Force = 24N

Input Force = 8N

Mechanical Advantage =

Speed Ratio

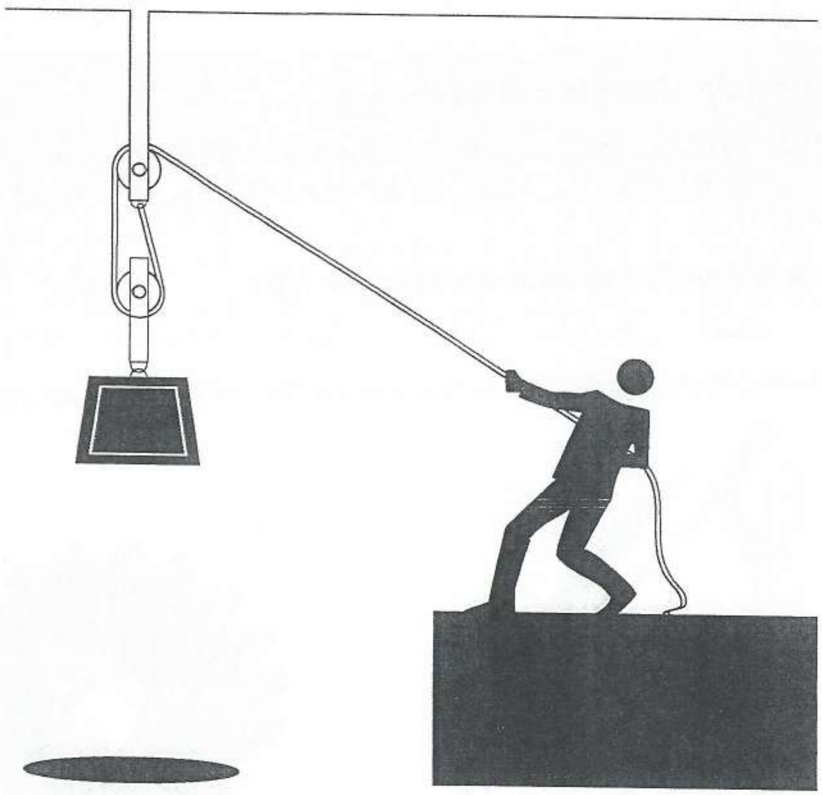
The speed ratio is how much faster you can do a task (job) by using a machine. Machines reduce the amount of time it takes to do the same amount of work and move the same distance.

E.g., How much faster you can lift a weight using a pulley.

Input Distance

Input distance is the length along which force is put in (for how long).

E.g., How far you pull the rope down.



Output Distance

Output distance is how far the device moves in total.

E.g., How far the weight moves upward.

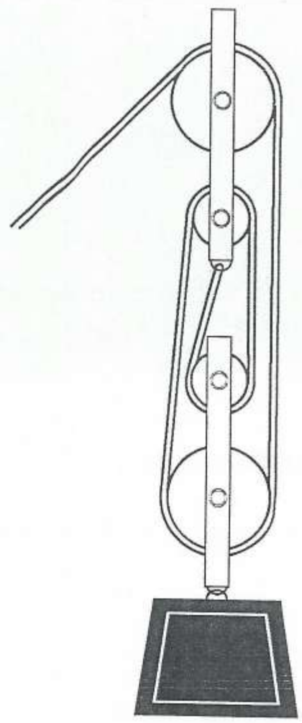
How to calculate Speed Ratio

Speed ratio calculations work opposite to mechanical advantage. It is calculated by **dividing** the total **input distance** by the total **output distance**. Remember, both distance amounts must be in the **same units.**

Note: Distance is usually measured in meters (m).

$$SR = \frac{D\ input}{D\ output}$$

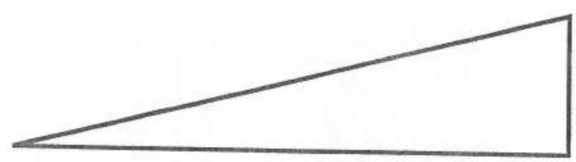
1. Calculate the speed ratio of the following mechanical devices.



Input Distance = 4m

Output Distance = 2m

Speed Ratio =



Input Distance = 6m

Output Distance = 2m

Speed Ratio =

2. Did you notice that more work was needed to move less distance in each case? That's because the mechanical devices makes the work easier, you just have to do it for longer! Can you think of a time when this wouldn't be an advantage?

____

____

____

Mechanical Efficiency

Mechanical efficiency is a measure of how well a machine uses energy. It is important to know because it helps you decide whether the amount of energy you have to put into it is worth what you get out.

How does friction affect efficiency?

Friction (the amount of force working against the machine) has the biggest effect on efficiency. Friction includes things like wind blowing against a machine, parts rubbing against the ground, and inner parts "sticking" from lack of lubrication.

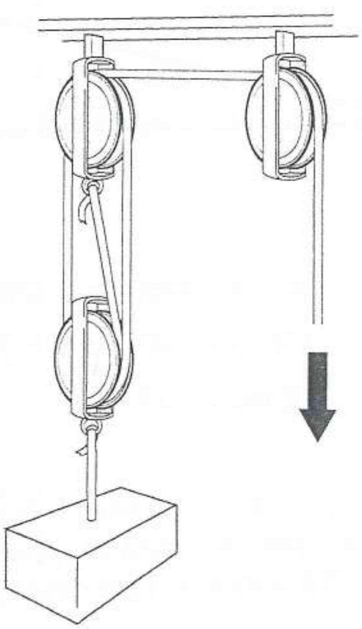
Another way to calculate efficiency

Efficiency is also calculated by dividing the mechanical advantage (the added force of using the machine) by the speed ratio (how far you get compared to how hard you work) and then multiplying by 100 to get a percent.

$$\textbf{Efficiency} = \frac{MA}{SR} \times 100$$

Note: Efficiency is described in percent (%) because it is being compared to a situation where no energy was wasted (that would be 100% efficient).

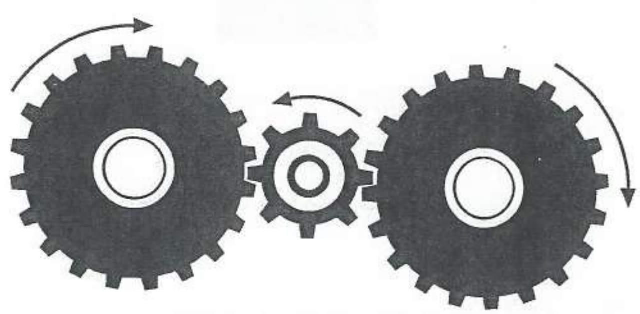
1. Calculate the efficiency of the following mechanical devices:



Mechanical Advantage = 6N

Speed Ratio = 2m

Efficiency =



Mechanical Advantage = 1N

Speed Ratio = 2m

Efficiency =

Calculate the mechanical advantage, speed ratio and efficiency of mechanical devices with the following recorded forces and distances. Show your work!

1. Input Force: 3N — Mechanical Advantage: ______ N

   Output Force: 6N — Speed Ratio: ______ m

   Input Distance: 12m — Efficiency: ______ %

   Output Distance: 4m

2. Input Force: 8N — Mechanical Advantage: ______ N

   Output Force: 16N — Speed Ratio: ______ m

   Input Distance: 18m — Efficiency: ______ %

   Output Distance: 3m

3. Input Force: 1N — Mechanical Advantage: ______ N

   Output Force: 1N — Speed Ratio: ______ m

   Input Distance: 10m — Efficiency: ______ %

   Output Distance: 5m

4. Are any of the mechanical devices above not worth using? Explain your answer.

   ____

   ____

5. Which mechanical device was likely working against the most friction? How do you know?

   ____

   ____

Part H: What does Pascal's Law have to do with it?

Pascal's Law

Pascal was a scientist who discovered that when fluids are put under pressure, it is spread out equally through the whole fluid.

Pressure

Pressure is a measure of the amount of force applied to a given area (how hard one thing pushes against another thing).

Fluid

Fluids are liquids and gases that flow (can be poured) and have no definite shape.

Hydraulic (hy-draw-lic) Equipment

Hydraulic equipment is a category of devices that use **liquids under pressure** to make it easier to do work.

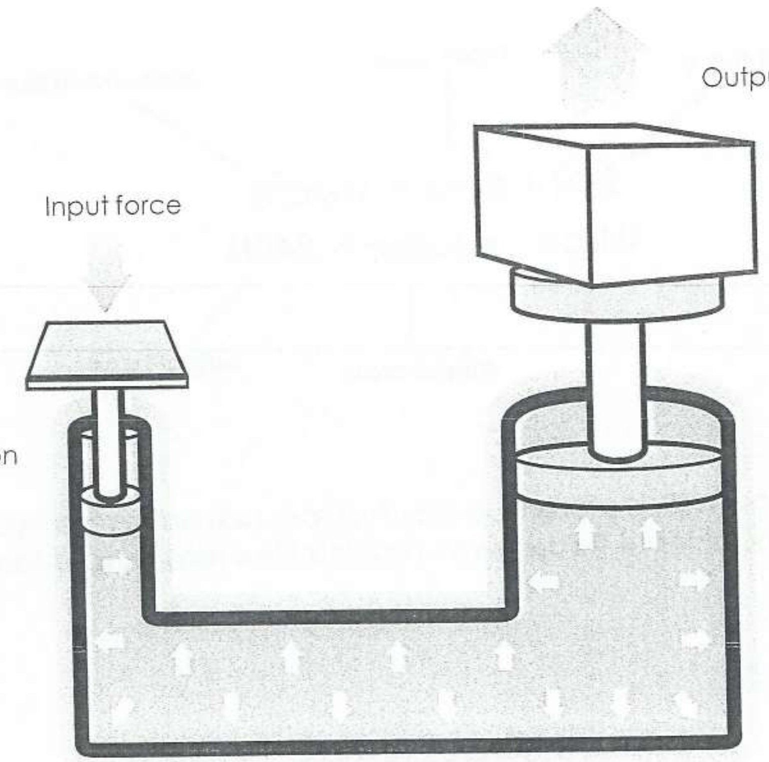
Pneumatic (new-mat-ick) Equipment

Pneumatic equipment is a category of devices that use **gases under pressure** to make it easier to do work.

Write an **H** beside the examples of **hydraulic equipment** and a **P** beside the examples of **pneumatic equipment**.

1. ____ Car brake systems are filled with pressurizedliquid brake fluid.
2. ____ A jack hammer uses compressed air.
3. ____ A dump truck uses liquid under pressure to lift the back bed.
4. ____ Many power tools are hooked to air compressors.
5. ____ A hair stylist's chair is raised and lowered using the power of compressed air.

How Hydraulic Systems Work



Two-Piston Hydraulic System

Pistons act like plungers pushing (putting pressure) on the fluid in a hydraulic system. The pressure spreads through the fluid and hits the output piston and pushes it up with the input pressure combined with the pressure built up in the fluid. How much pressure in total depends on the input force and the size of the pistons.

If, in the diagram above, the input force is 24N, the area of the input piston is $6cm^2$, and the area of the output piston is $60cm^2$, the calculation to find output force involves finding the missing number in a set of equivalent fractions (they are equivalent because pressure is equally shared in fluids).

$$\frac{\textbf{F}\ \textit{input}}{\textbf{A}\ \textit{input}} = \frac{\textbf{F}\ \textit{output}}{\textbf{A}\ \textit{output}} \qquad \frac{24N}{6cm^2} = \frac{?}{60cm^2}$$

To find the missing number, divide the numbers in the complete fraction and then multiply to find the missing number.

input force — input area — pressure in the system

$$24N \div 6cm^2 = 4N/cm^2$$

$$4N/cm^2 \times 60cm^2 = \mathbf{240N}$$

output area — output force

Do you notice how much more of a mechanical advantage a hydraulic system gives you? 24 Newtons of input force gives you 240 Newtons output force – ten times the amount!

Use the information on the previous page to help you answer the following questions.

1. What is a hydraulic system?

____

____

____

2. What is the difference between input force and output force?

____

____

____

3. How is pressure built in a hydraulic system?

____

____

____

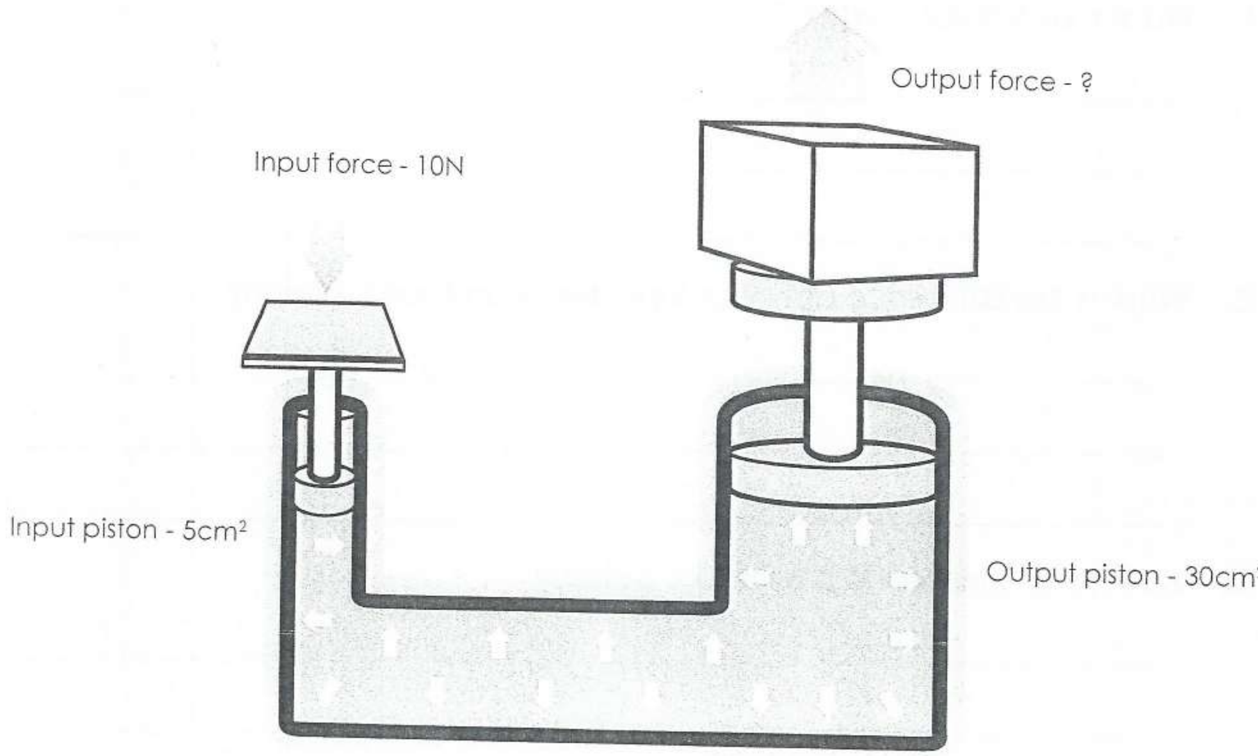
4. How helpful are hydraulic systems? How do you know?

____

____

____

5. Calculate the pressure and the output force of this hydraulic system.



Part I: How do you know when it's worth it?

Use the following SAFE-DEE list to help you assess (evaluate) two different mechanical devices found in your home or school that can be used to do similar jobs. Then, on the next page, explain which one is a "better bet" and why.

Note: An adult must be present when examining or using any dangerous equipment.

Assessing a Mechanical Device Using SAFE-DEE

Safety
Are there any dangers associated with using it?

Availability
How easy is it for people to get one?

Function
What job does it do? How important is that job?

Efficiency
How much easier does it make the task?

Design
Is it well made?

Effectiveness
How well does it do its job?

Expense
How much does it cost? Is the cost reasonable?

The mechanical devices I assessed were:

_______________ _______________

The job(s) they both do is/are:

What I learned from my SAFE-DEE assessment:

What other criteria could you consider when assessing a mechanical device?