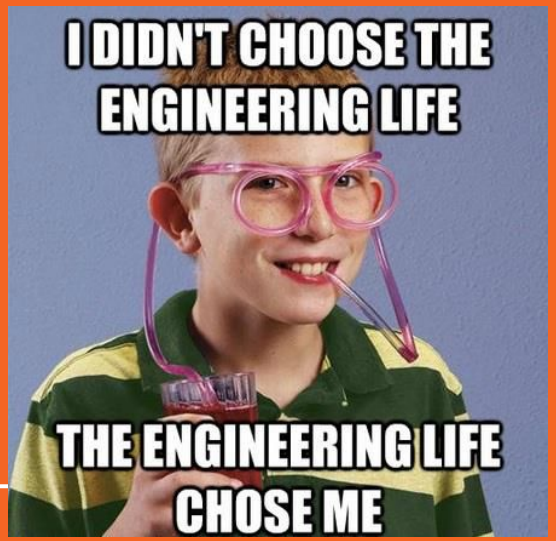
Unit 2
Mechanical Systems



Simple Machines

- change direction
- multiply force
- change speed
- transfer force

Levers

Inclined Plane (Ramp)

Wedge

Screw

Pulley

Wheel and Axle

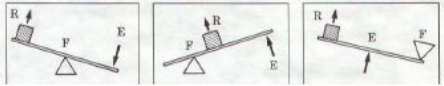
Machines from the Past

Aqueduct

Sakia

Archimedes Screw

1st Class Lever | 2nd Class Lever | 3rd Class Lever



Work = **F**orce x **d**istance

Mechanical Advantage	Speed Ratio
MA = Output force / Input force	**SR** = Input distance / Output distance

Efficiency = MA / SR x 100

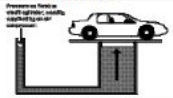
Machine Efficiency

Efficiency = $\text{Work}_{\text{output}}$ / $\text{Work}_{\text{input}}$ x 100

Pascal's Law

Pressure is transmitted equally in all directions throughout an enclosed fluid.

Pressure = Force / Area

Hydraulics	Pneumatics
	

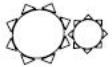
Force of the small piston / Area of the small piston = Force of the large piston / Area of the large piston

Complex Machines

System
↓
Subsystems
↓

Gears

Multiplying



Reducing

Parallel

Linkage

Transmission

Mousetrap Vehicle

Evaluation Criteria

Efficiency	Effectiveness	Function	Design	Cost	Improvement
Safety	Convenience	Esthetics	Packaging	Environmental Impact	

Societal and Technological Impact of Machines

Block and Tackle

Steam Engine

Bicycles

Early

Modern

Egg Beater

Pop Can Tab

MagLev Trains

Robots

Critical Thinking

1. Define your topic (you can use the glossary or index of your textbook to help you do this).

2. Talk to your group and write down what you already know about your topic.

3. Give two ideas/examples from the real-world that are related to your topic.

4. Analyze why a scientist would be motivated to study this topic.

1.0 Machines are tools that help humans do work.

Learning Outcomes

- Describe examples of mechanical devices used in the past to meet particular needs
- Describe an example of how a common need has been met in different ways over time
- Analyze a mechanical device by describing how different parts contribute to its overall function and identifying the parts that are simple machines
- Identify the sources of energy for some familiar mechanical devices
- Identify linkages and transmissions in a mechanical device and describe their general function

What if the world lost oxygen for 5 seconds?

Machines

A machine is a mechanical structure that uses power to apply forces and control movement to perform an intended action.

Machines make tasks easier by using a **Mechanical Advantage**.

Machines

Machines were originally created to transport water. Without water crops could not be grown, livestock could not be taken care of and people could not survive.

The machine built to transport water was the Roman Aqueduct.

Mechanical Advantage

Mechanical advantage is the ratio of the force produced by a machine (output) to the force applied to it (input). Mechanical advantage calculations are used in assessing the performance of a machine.

$$\text{Mechanical Advantage} = \frac{\text{Output Force}}{\text{Input Force}}$$

To pull a weed out of a garden, you can apply a force of 50 N to the shovel. The shovel applies a force of 600 N to the weed. What is the mechanical advantage of the shovel?

Input =

Output =

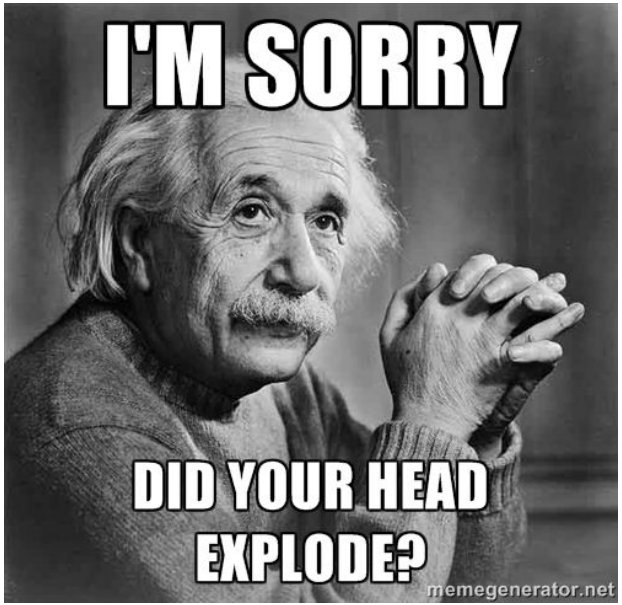
$$\text{Mechanical Advantage} = \frac{\text{Output Force}}{\text{Input Force}}$$

Imagine that you are lifting a patio stone using a pry bar as a lever. If the input force applied is measured as 25 N and the output force is measured as 250 N, what is the mechanical advantage?

Mechanical Advantage

Ideal mechanical advantage is what the mechanical advantage would be if all of the input force could be converted into an output force. However, this is never possible in real-world applications.

Actual mechanical advantage is the mechanical advantage that actually occurs. It is the ideal mechanical advantage minus any force lost to factors such as internal friction, slippage, and distortion.



Mechanical Advantage

It is possible to have a **mechanical advantage less than 1**. This happens when the input force is greater than the output force.

Though it seems bad, a mechanical advantage less than 1 does have its' advantages.
A hockey stick for example, requires an input force much greater than the output force.
The benefit of the hockey stick is that it increases the distance and speed of the output.

Trial and Error

Of course things do not always work on the first try, and so many people failed throughout time. However, through trial and error correct methods have been reached.

Trial and error is a fundamental method of problem solving.

Examples of trial and error

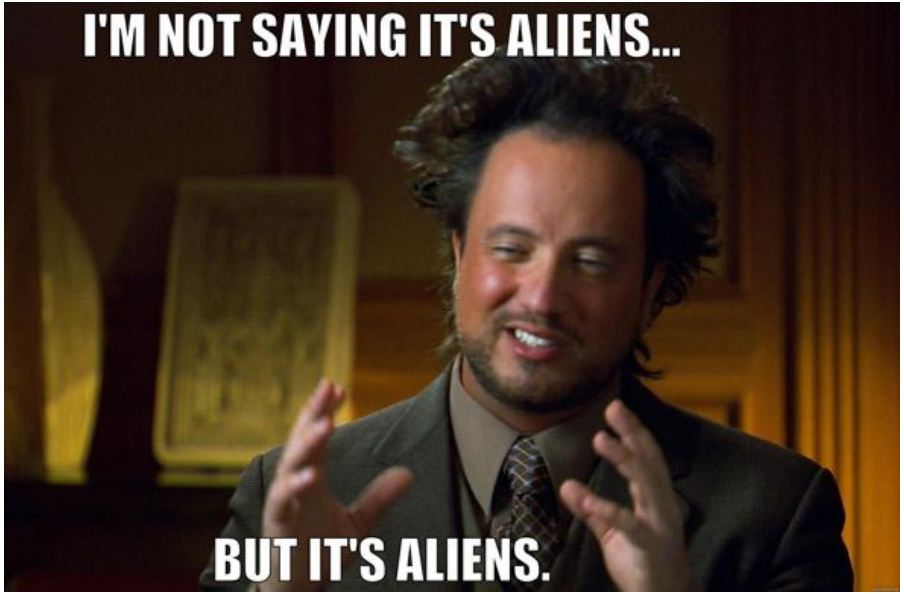
While watching the Road Runner clip, identify at least two examples of trial and error by the Coyote.

Review

a) What is trial and error?

b) What is mechanical advantage?

c) When is it advantageous to have a mechanical advantage less than 1?



Simple Machines

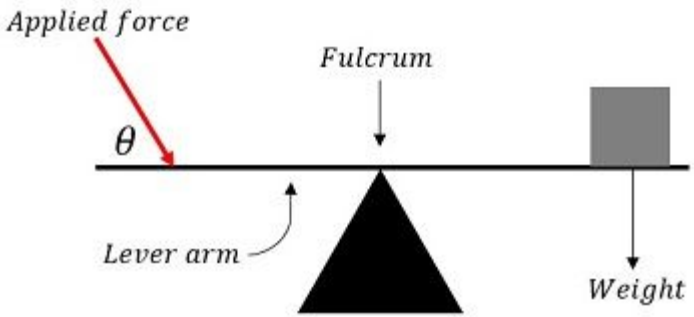
Simple machines are tools that make work easier. They have few or no moving parts and use energy to work. There are six simple machines, they are the;

1) Lever
2) Inclined Plane
3) Wedge
4) Wheel and Axle
5) Pulley
6) Screw

The Lever

The Lever is a ridged plank that rotates around a fixed point called a **fulcrum**.

A lever can move a heavy load, but as the load increases so must the length of the lever in order to keep input force the same.



Advantages and disadvantage of the lever

Advantage

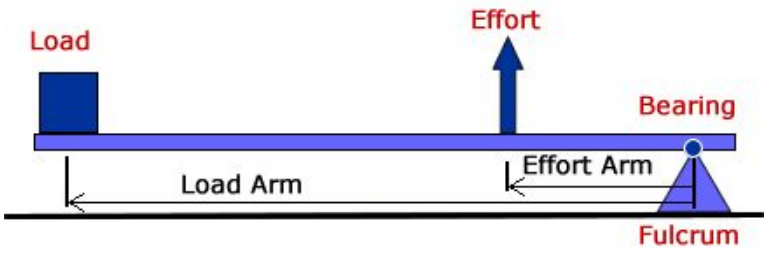
Levers can lift larger and larger loads with the same amount of input force as long as the length of the lever increases.

Disadvantage

The longer the lever is, the more distance you must travel even though the load distance stays the same

Mechanical advantage of the lever

To find the Mechanical Advantage for the lever we use distance instead of force.



$$\text{Mechanical Advantage} = \frac{\text{Distance to input force}}{\text{Distance to output force}}$$

The distance from the fulcrum to the effort force applied is 120cm. The distance from the fulcrum to the load applied to the lever is 30cm. What is the mechanical advantage of the lever?

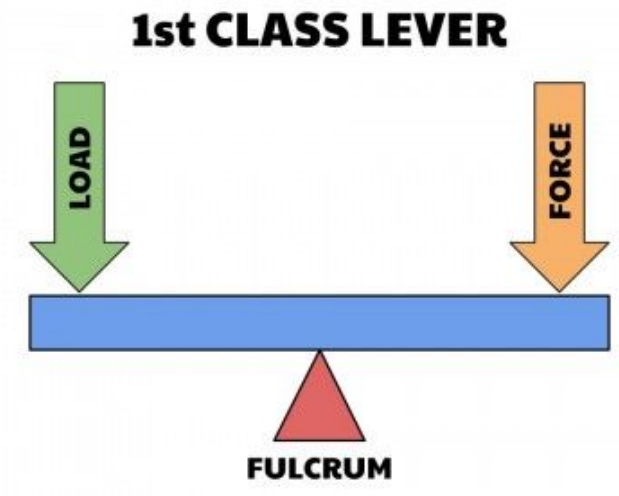
The distance from the fulcrum to the effort force applied is 40cm. The distance from the fulcrum to the load applied to the lever is 80cm. What is the mechanical advantage of the lever?

First class lever

A **first class lever** has the fulcrum between the load and the effort force.

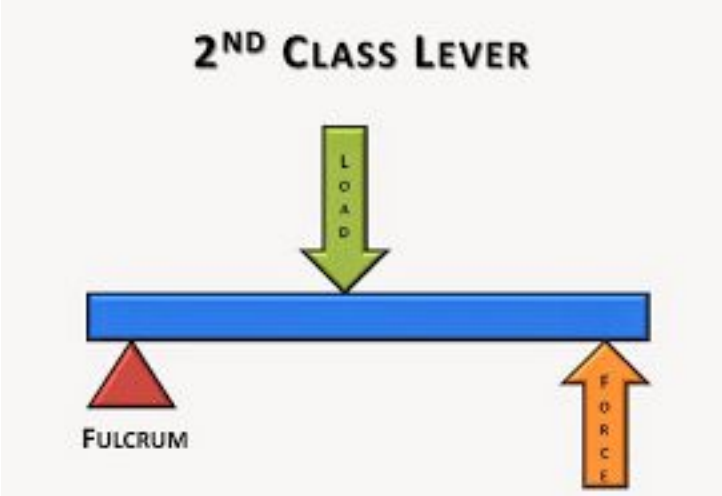
First-class levers have a considerable practical advantage over the other types of levers. They convert a downward moving force into a lifting force. This means that you can always augment your ability to lift a load across a teeter-totter style lever simply by using the force of gravity.

Some examples of first class levers are; scissors, teeter totters and pistons.



Second Class Lever

A **second class lever** has load between the effort force and the fulcrum.



In a second class lever the effort moves over a large distance to raise the load a small distance. As the ratio of effort force arm length to load arm length increases, the mechanical advantage of a second class lever increases.

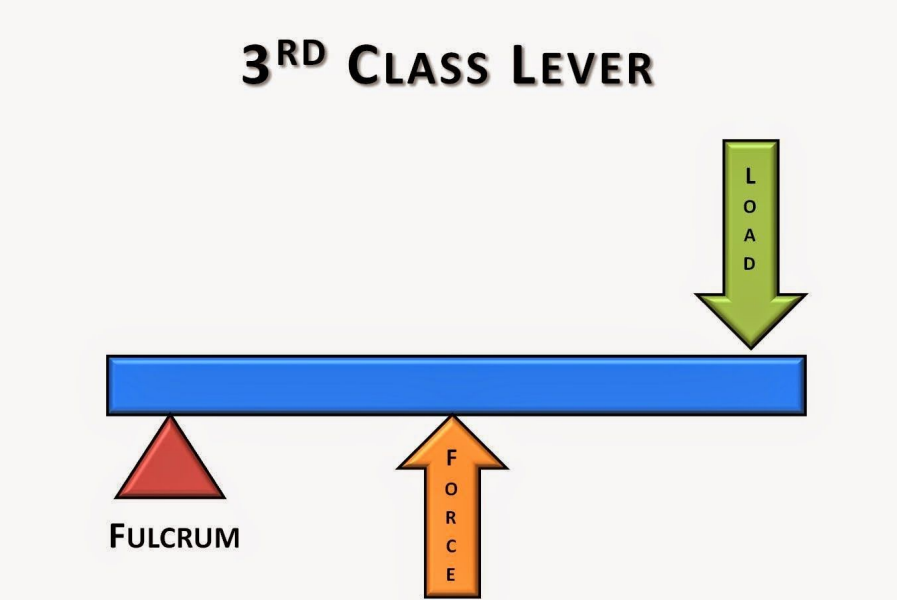
An example of a second class lever is a wheelbarrow.

Third Class Lever

A third class lever has the effort between the load and the fulcrum.

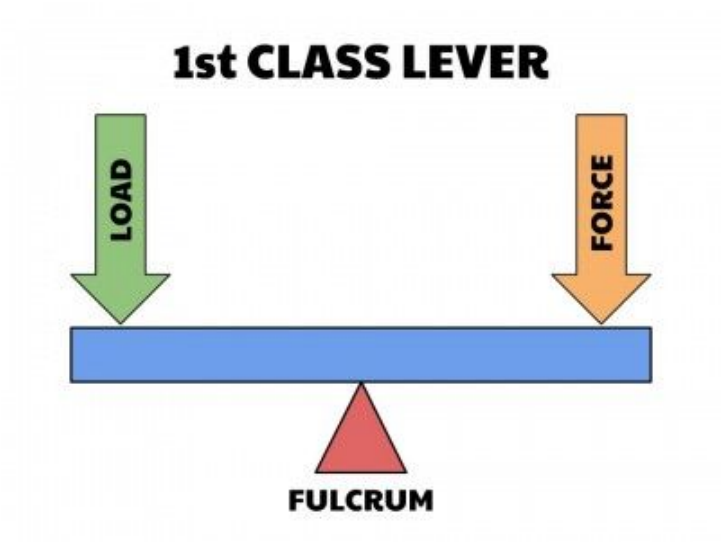
In a third class lever the load moves further than the effort force and the mechanical advantage is low, which is why it's difficult to apply great force to the load.

Examples of third class levers barbeque tongs, and hockey sticks.



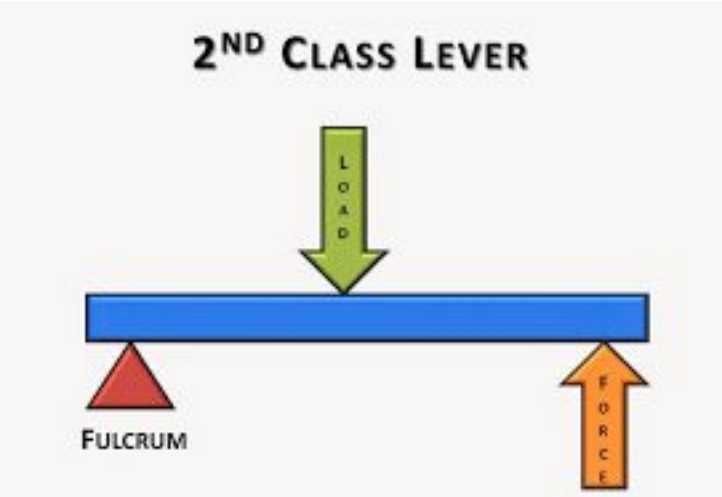
What kind of lever?

First Class Lever



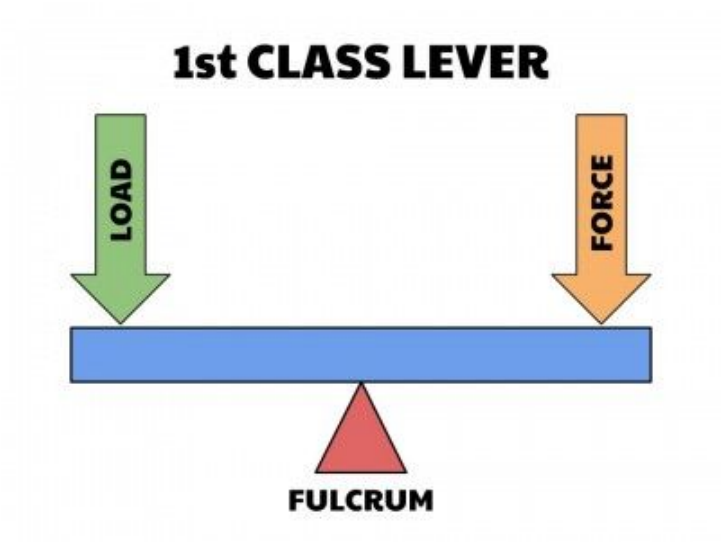
What kind of lever?

Second Class Lever



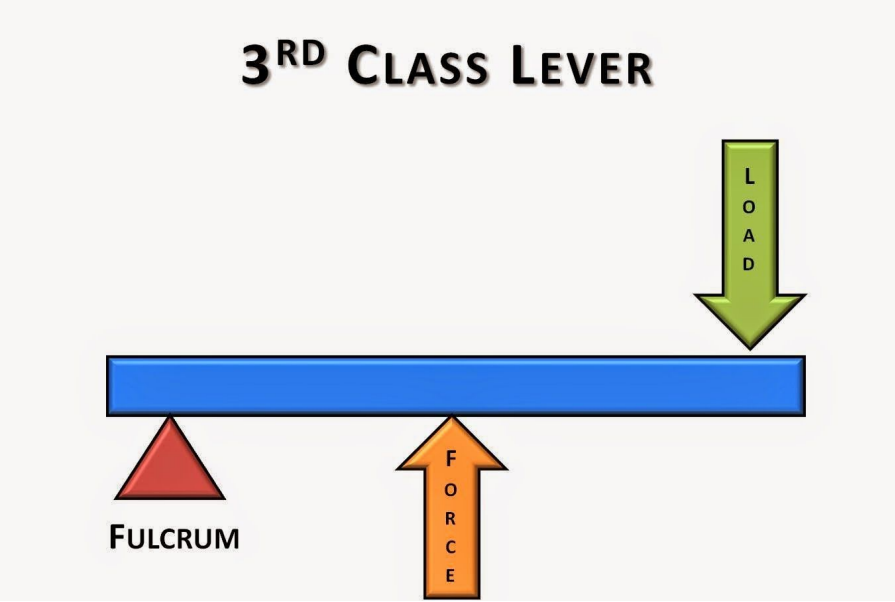
What kind of lever?

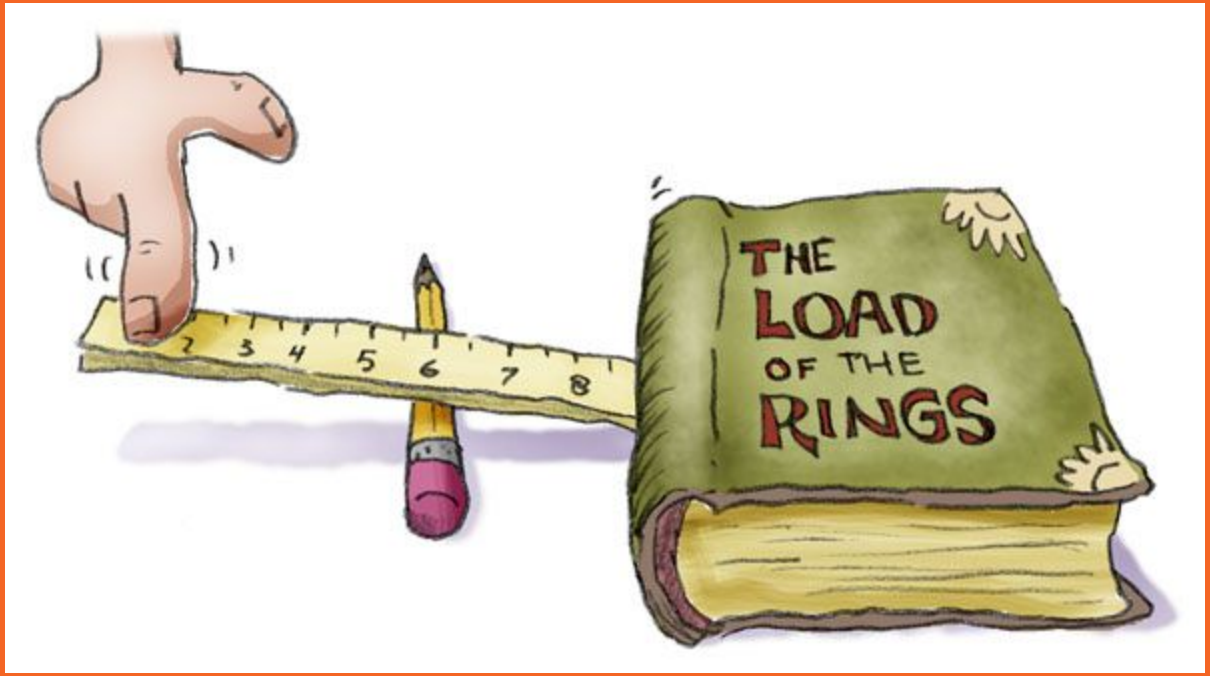
First Class Lever



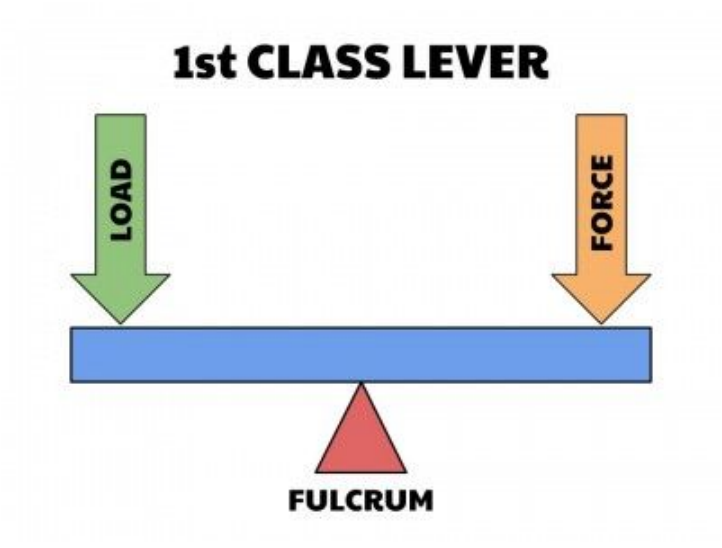
What kind of lever?

Third Class Lever




THE
LOAD
OF THE
RINGS

First Class Lever



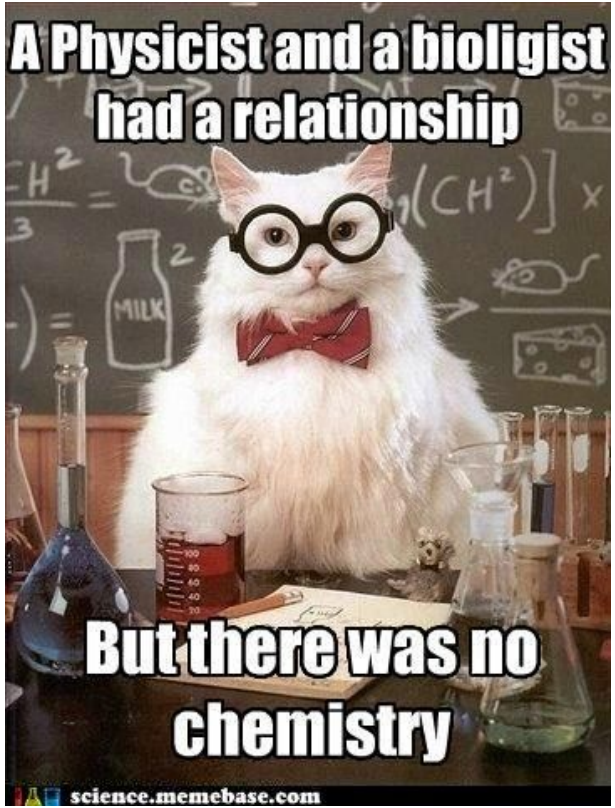
What if your airplane door opened during flight?

Review

a) What are the three kinds of levers?

b) What is a disadvantage of levers?

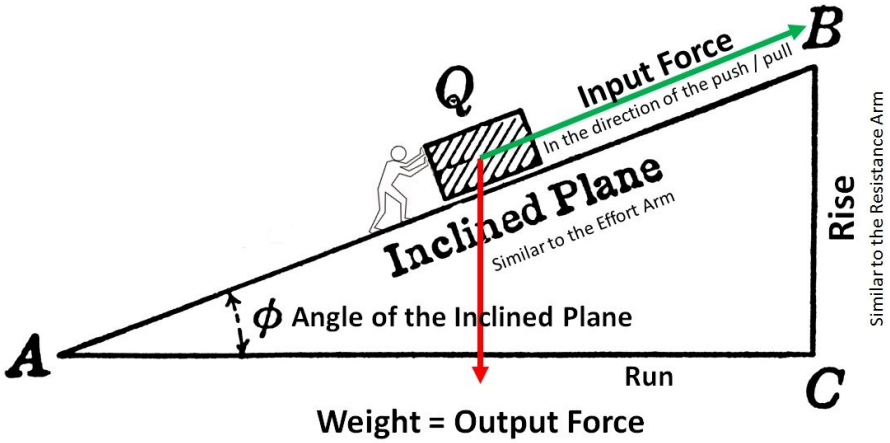
c) How do we measure the mechanical advantage of the lever?



The Inclined Plane

The Inclined Plane is a plane surface set at an angle, against a horizontal surface. an inclined plane has both a horizontal component and vertical component.

When lifting an objecting upwards the downward force of gravity resists this. The inclined plane helps to alleviate this problem by pushing an object over a distance.



Advantages and disadvantages of the inclined plane

Advantage

Inclined planes allow you to exert a smaller force to lift an object as opposed to lifting it straight up

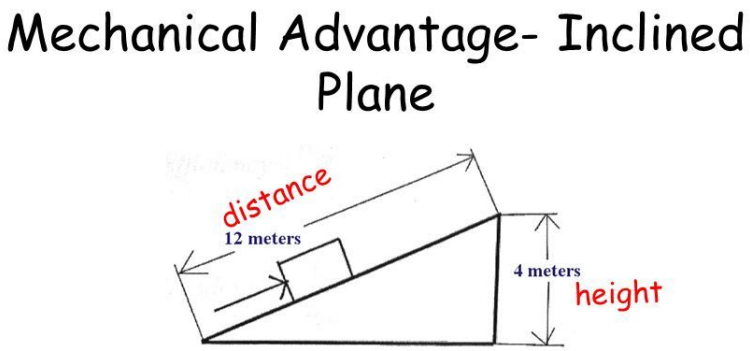
Disadvantage

You have to exert the smaller lifting force over a greater distance compared to lifting it straight up

Mechanical advantage of the inclined plane

The Mechanical Advantage formula for the inclined plane is measured by taking the length of the hypotenuse and dividing by the height of the inclined plane.

$$\text{Mechanical Advantage} = \frac{\text{Length of hypotenuse}}{\text{Height of plane}}$$



What is the mechanical advantage of an inclined plane that is 6 meters long and 3 meters high?

What is the mechanical advantage of an inclined plane that is 10 meters long and 7 meters high?

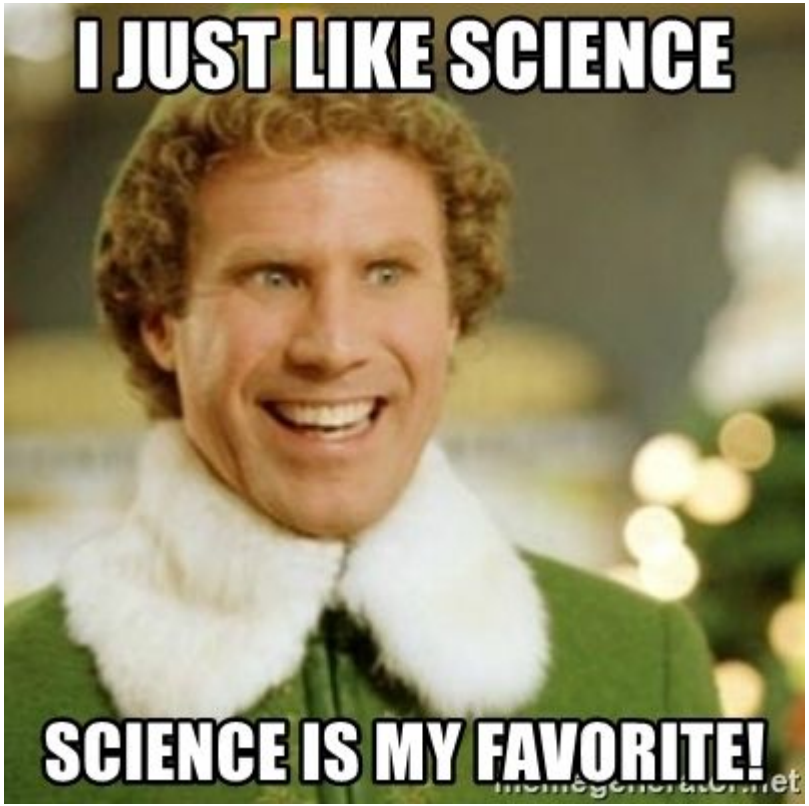
What is the mechanical advantage of an inclined plane that has a base of 4 metres and a height of 3 metres?

Review

a) How do you calculate the mechanical advantage of an inclined plane?

b) What is the difference between mass and weight?

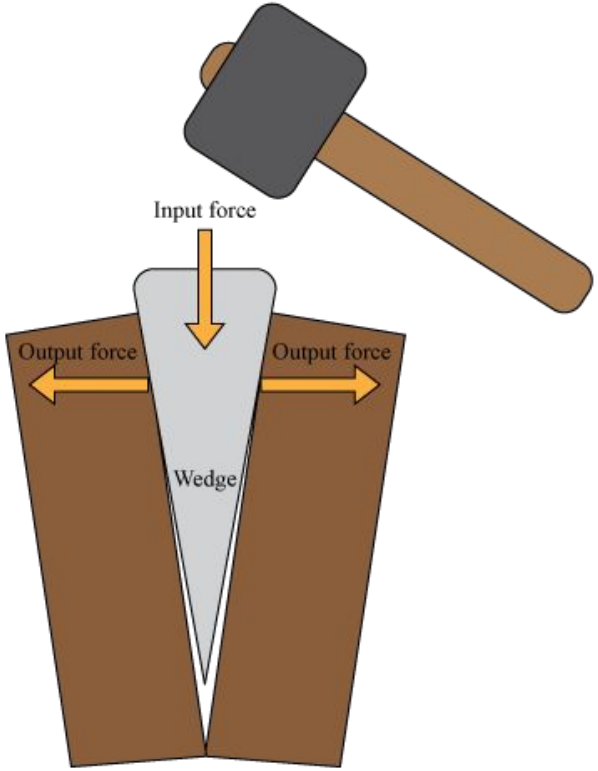
c) What is a disadvantage to the inclined plane?



The Wedge

Wedges are a kind of inclined plane, but because of their usefulness are their own category of simple machine.

Wedges work by concentrating a force applied to the wide end of the wedge, to a small area at the narrow end of the wedge. After applying the force the wedge redirects the downward force to an outward force.



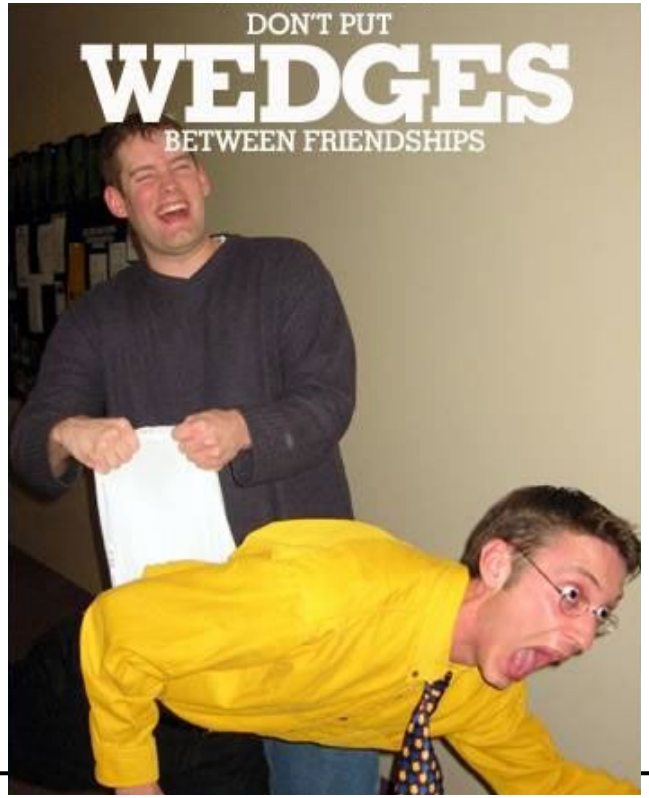
Advantages and disadvantages of the wedge

Advantage

The wedge increase the force you apply from a large surface area to a narrow surface area

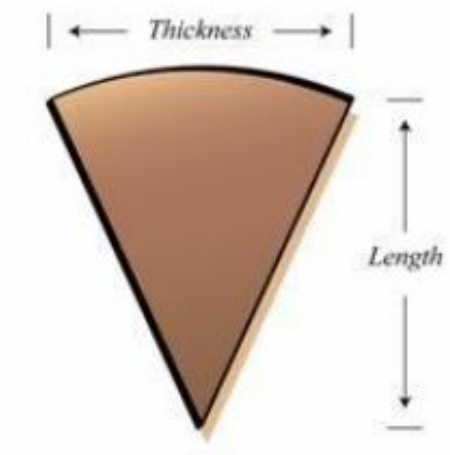
Disadvantage

The wedge will travel a greater distance into the object you apply the force to and it can only be used in one direction



Mechanical advantage of the wedge

Calculating the mechanical advantage of a wedge is the same as calculating the mechanical advantage for an inclined plane. The ideal mechanical advantage of a wedge is determined by dividing the length of the wedge by its width.



$$\text{Mechanical Advantage} = \frac{\text{Length of hypotenuse}}{\text{Height of plane}}$$

If the head of an axe has a length of 30cm and a width of 10cm what is it’s mechanical advantage?

Wedge or not?

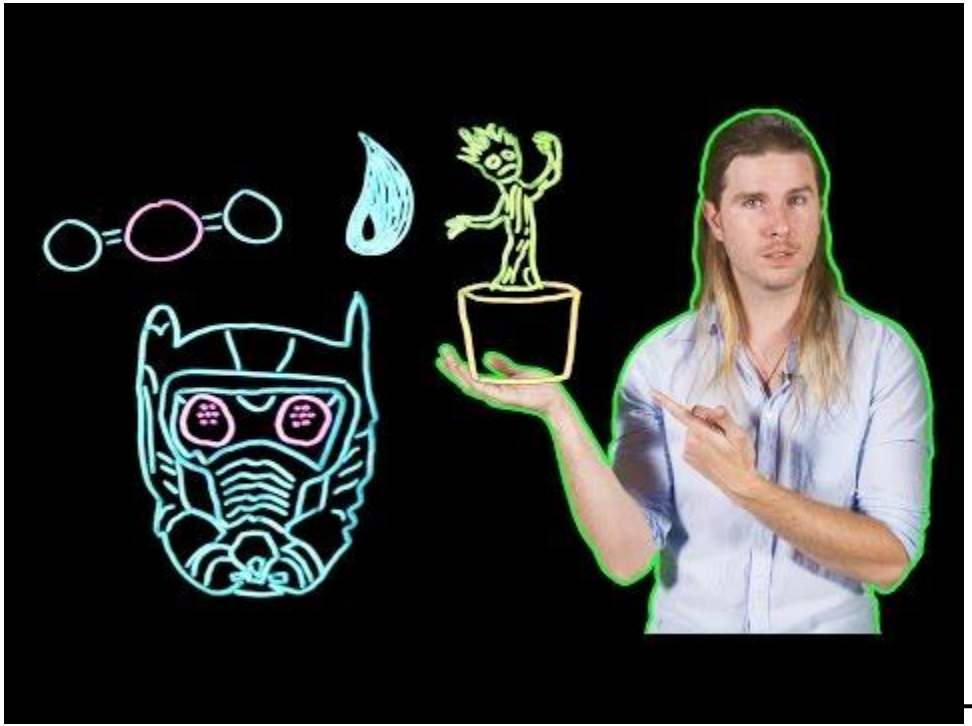
Wedge or not?

Wedge or not?

Wedge or not?

Wedge or not?

What is Groot made of?

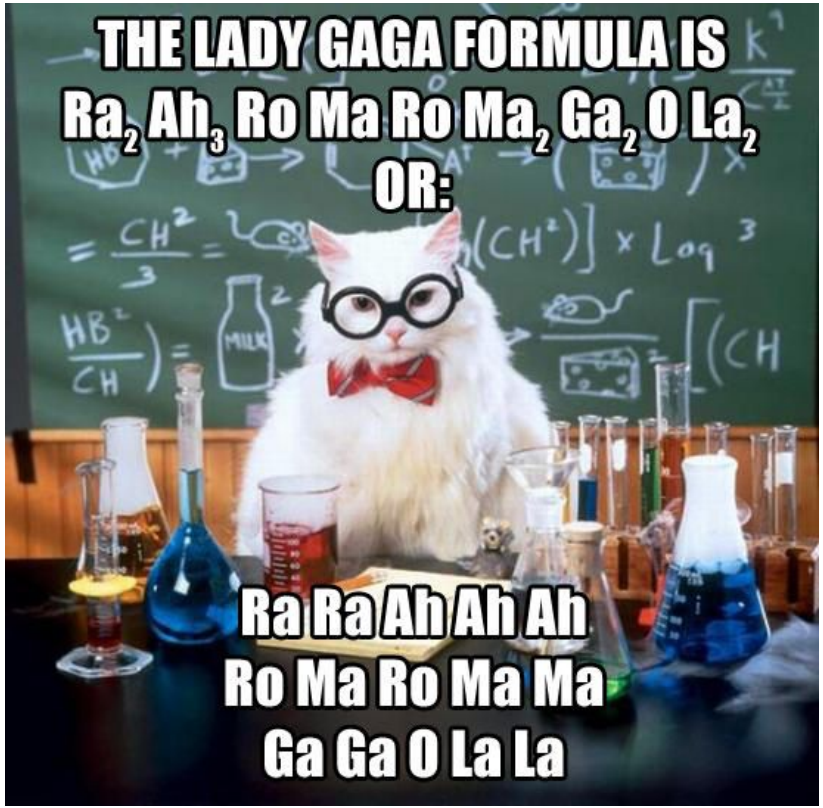


Review

a) How do you calculate the mechanical advantage of a wedge?

b) What is an example of a wedge?

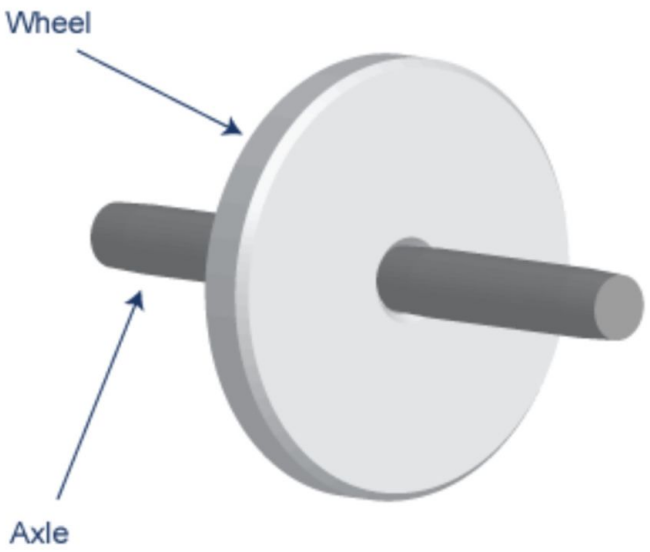
c) What is a disadvantage of the wedge?



The Wheel and Axle

The wheel and axle are a combination of two different diameter wheels that turn together

A longer motion on the wheel produces a shorter but more powerful motion at the axle.



Advantages and disadvantages of the wheel and axle

Advantage

A longer motion on the wheel produces a shorter but more powerful force on the axle

A wheel and axle can be used to increase speed when the force is applied to the axle instead

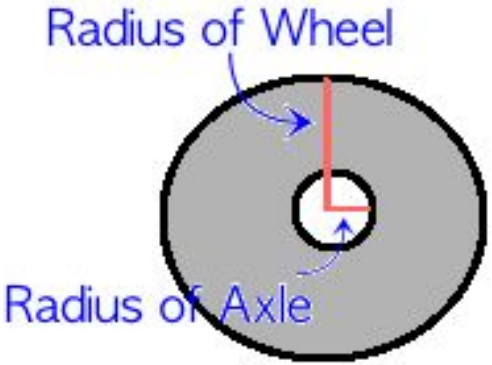
Disadvantage

You need to turn the wheel a greater distance to apply force.

Mechanical advantage of the wheel and axle

The mechanical advantage of the wheel and axle is the ratio of the radius of the wheel over the radius of the axle.

$$MA = \frac{\text{Radius of Wheel}}{\text{Radius of Axle}}$$



If a wheel's radius is 60cm and its axle is 30cm, what is the mechanical advantage of the wheel and axle?

If the wheel radius is 5m and axle radius is 2m. What is the mechanical advantage of the wheel and axle?

If the wheel area is $50m^2$ and axle radius is 2m. What is the mechanical advantage of the wheel and axle?

What if we detonated a nuke deep in the ocean?

Review

a) How do you calculate the mechanical advantage of the wheel and axle?

b) What is an example of the wheel and axle?

c) What is a disadvantage of the wheel and axle?

The Pulley

A pulley consists of a rope or cable moving on a grooved wheel which can be fixed in place or movable.

Pulleys help reduce the force needed to lift an object, by changing the direction of the force applied.

Advantages and disadvantages of the pulley

Advantage

Pulleys reduce the force needed to lift an object as long as it is attached to the load you are moving.

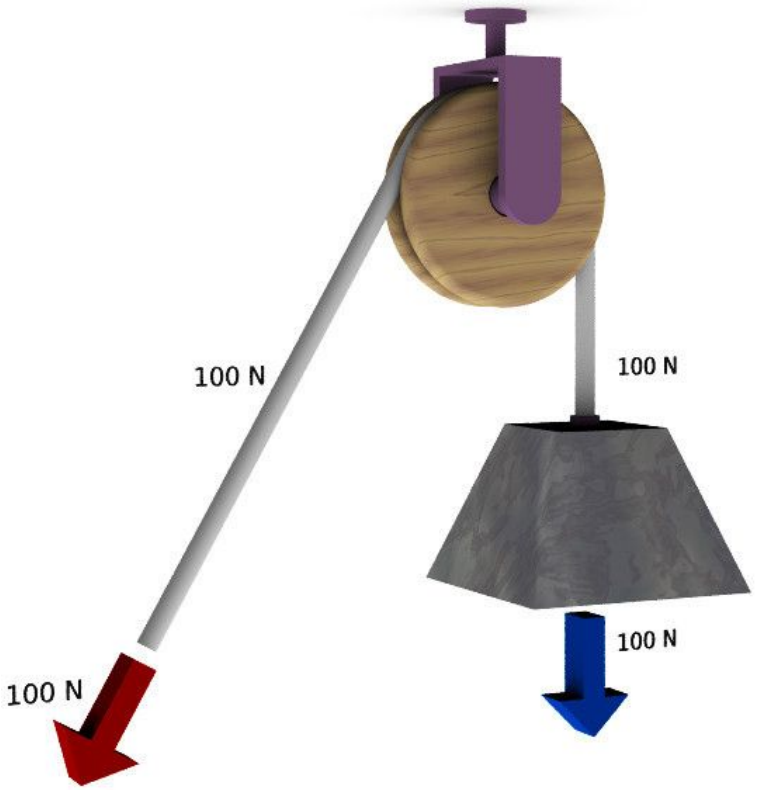
Disadvantage

The more you use pulleys to reduce the force needed, the greater the distance you will have to pull on the other end of the rope (twice as much input distance for each pulley reducing the input force by half)

Fixed Pulley

A fixed pulley changes the direction of the force on a rope or belt that moves along its circumference.

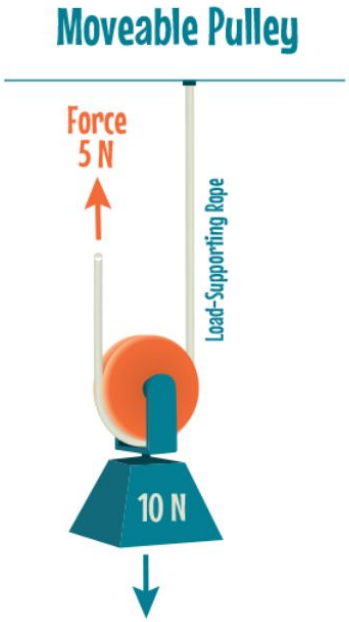
A good example of a fixed pulley is a flag pole: When you pull down on the rope, the direction of force is redirected by the pulley, and you raise the flag.



Moveable Pulley

A movable pulley has an axle in a movable block. A moveable pulley supports an object with two ropes, placing the pulley in the middle. Since the pulley is being supported by two ropes, the amount of force you need to move an object is cut in half.

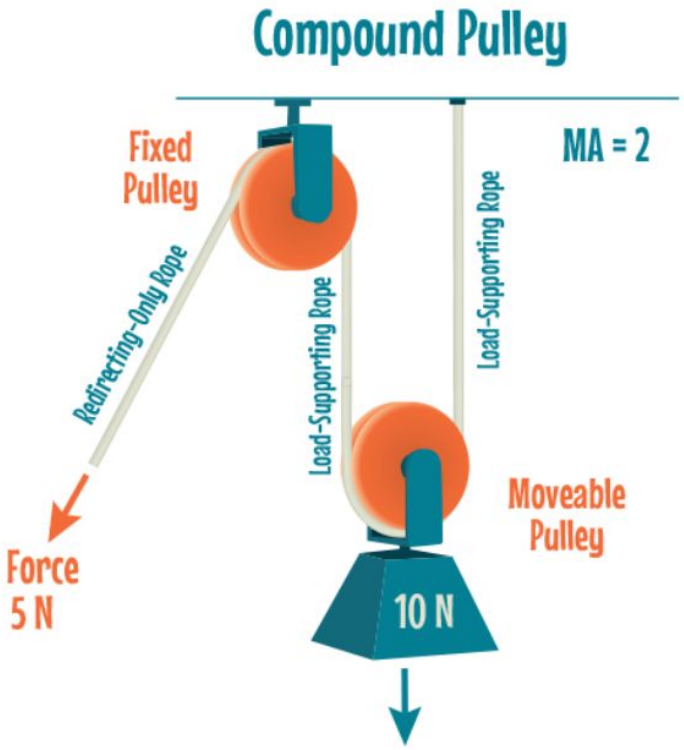
An elevator is an example of a moveable pulley.



Compound Pulley

A compound pulley is a combination of a fixed and movable pulley that forms a block and tackle, which can have several pulleys mounted on the fixed and moving axles, thereby increasing the amount of force.

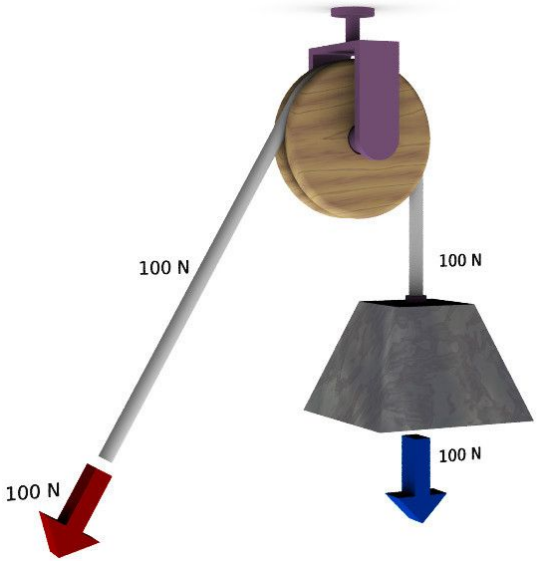
The **block and tackle** has been a key tool for raising boat sails and cargo for centuries.



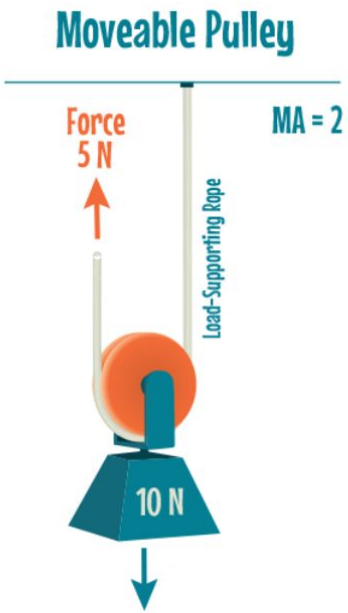
Mechanical advantage of the pulley

To calculate the mechanical advantage of a pulley you simply have to count the number of rope sections that support whatever object you are lifting.

For example the fixed pulley has a mechanical advantage of 1.



What is the mechanical advantage?



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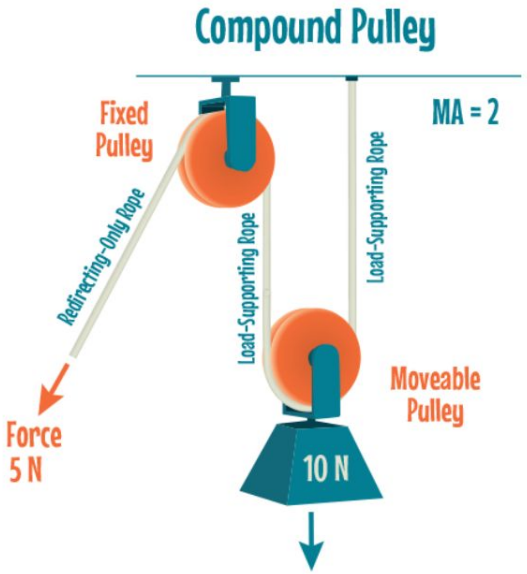

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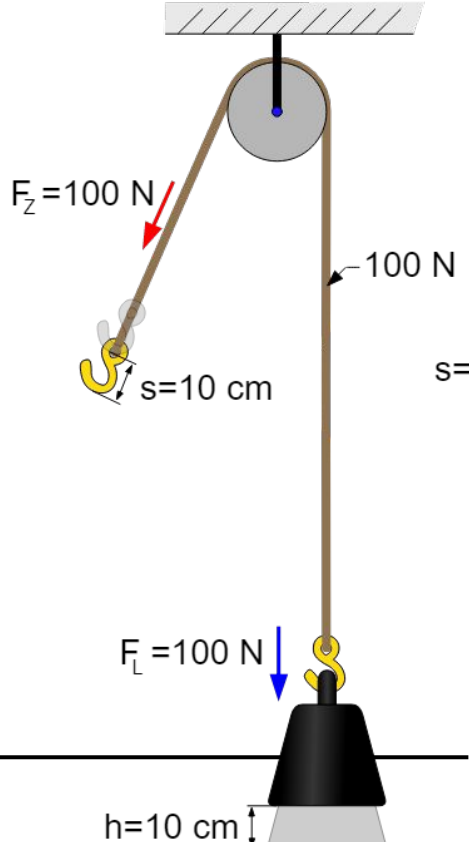

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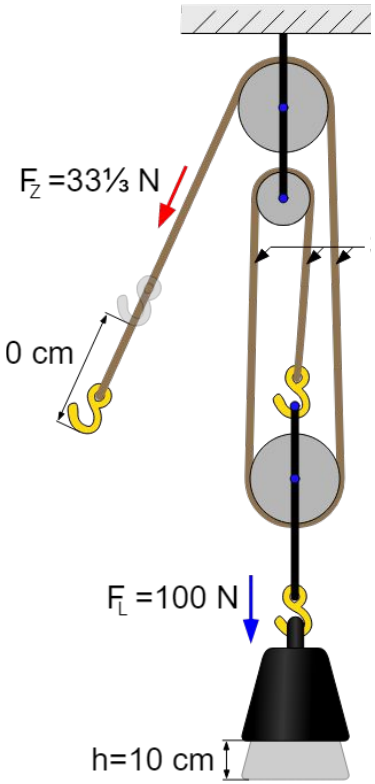

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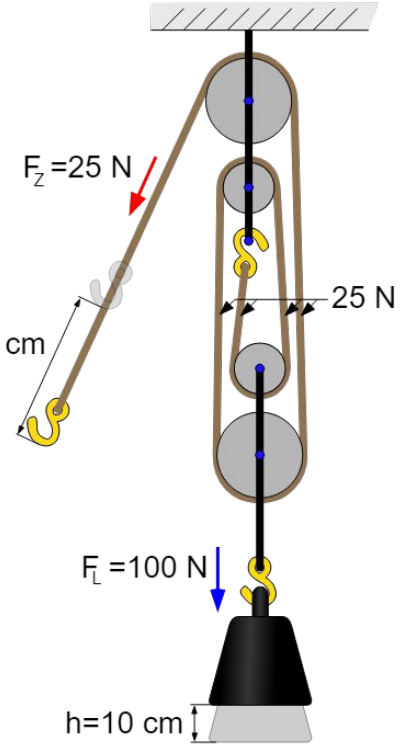


What if you only drank energy

Review

a) How do you calculate the mechanical advantage of the pulley?

b) What are the three types of pulleys?

c) What is a block and tackle?

The Screw

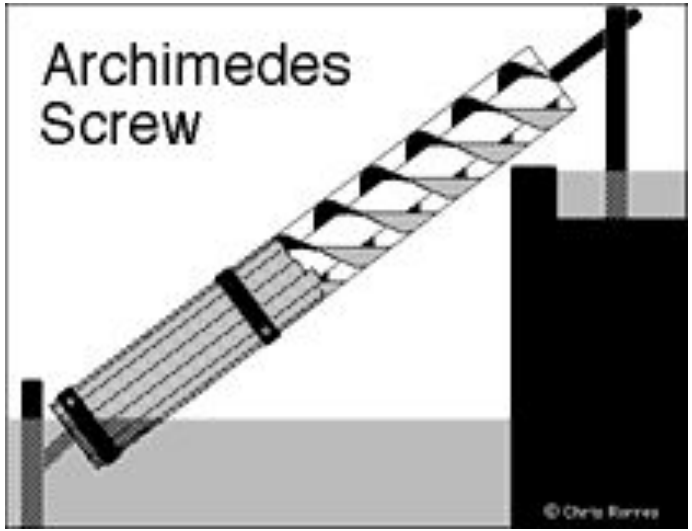
The screw is an inclined plane wrapped around a cylinder with a groove cut in a spiral on the outside. It can be used to penetrate materials or can be used to convert rotational motion into the linear motion of a fluid.

The screw is covered in edges called **threads**.

Archimedes Screw

An Archimedes' screw, is a machine used for transferring water from a low-lying body of water into irrigation ditches. Water is pumped by turning a screw-shaped surface inside a pipe.

Archimedes screws are used in sewage treatment plants because they cope well with varying rates of flow and with suspended solids.



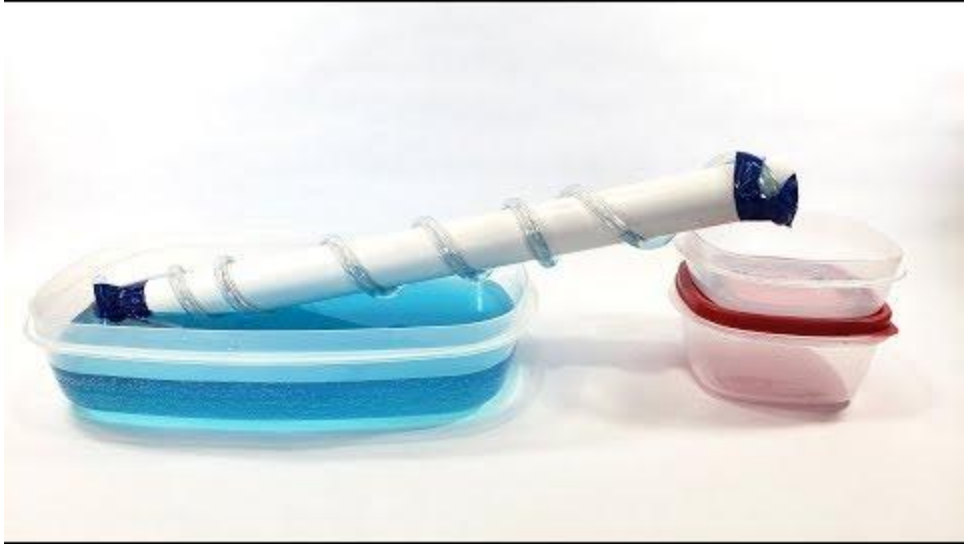
Advantages and disadvantages of the screw

Advantage

The screw will move most objects in linear motion which can be used to raise fluids.

Disadvantage

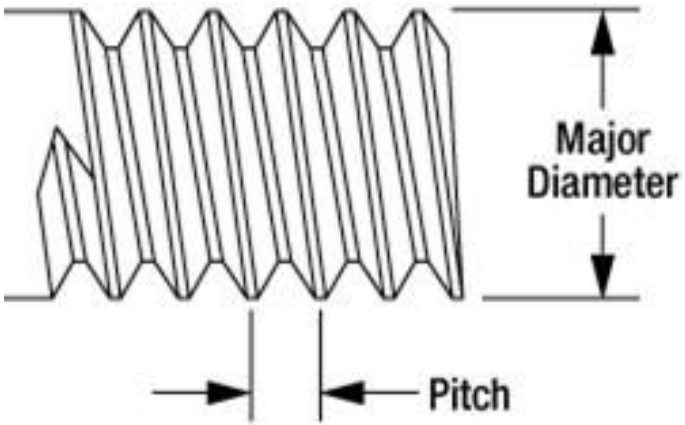
A large force must be applied to the axle of the screw in order to move an object very slowly.



Mechanical Advantage of the Screw

To calculate the mechanical advantage of a screw you divide the circumference of the screw by the pitch of the screw. Pitch is the vertical distance between two adjacent threads.

$$= \frac{Circumference\ \ of\ \ screw}{Pitch\ \ of\ \ screw}$$



What is the mechanical advantage of a screw with a pitch of 5 inches, and a circumference of 10 inches?

What is the mechanical advantage of a screw with a pitch of ⅛, and a circumference of 0.79 inches?

If a screw has a diameter of 0.25 inches, and a pitch of 0.3 inches, what is the mechanical advantage of the screw?

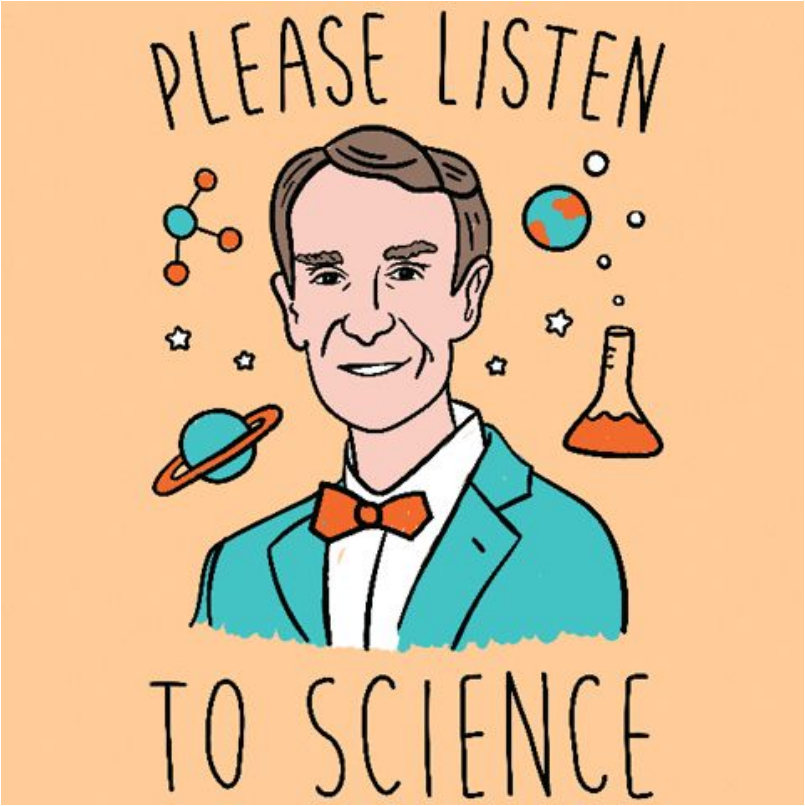
What if there was a black hole in

Review

a) What is the pitch of a screw?

b) What is the disadvantage of the screw?

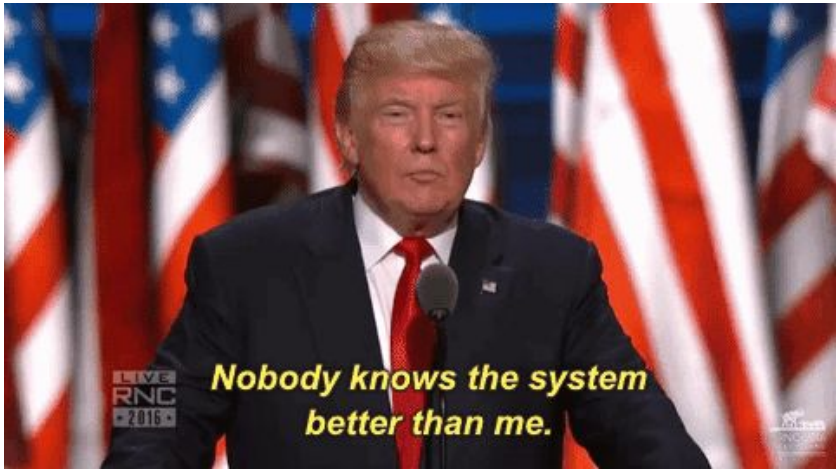
c) What are the six simple machines?



Systems and subsystems

A **system** is a group of parts that work together to perform a single function within a machine. The motor on a backhoe would be a system designed for converting chemical energy to mechanical energy

A **subsystem** is a single simple machine within the system that performs one task. The lever of a can opener is an example of a subsystem



Complex Machines

Complex machines are machines made up of two or more simple machines.

A complex machine is a series of systems in which several simple machines work together.

Example!

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 subsystems.

Identify the subsystems, systems and complex machines in Star Wars

Review!

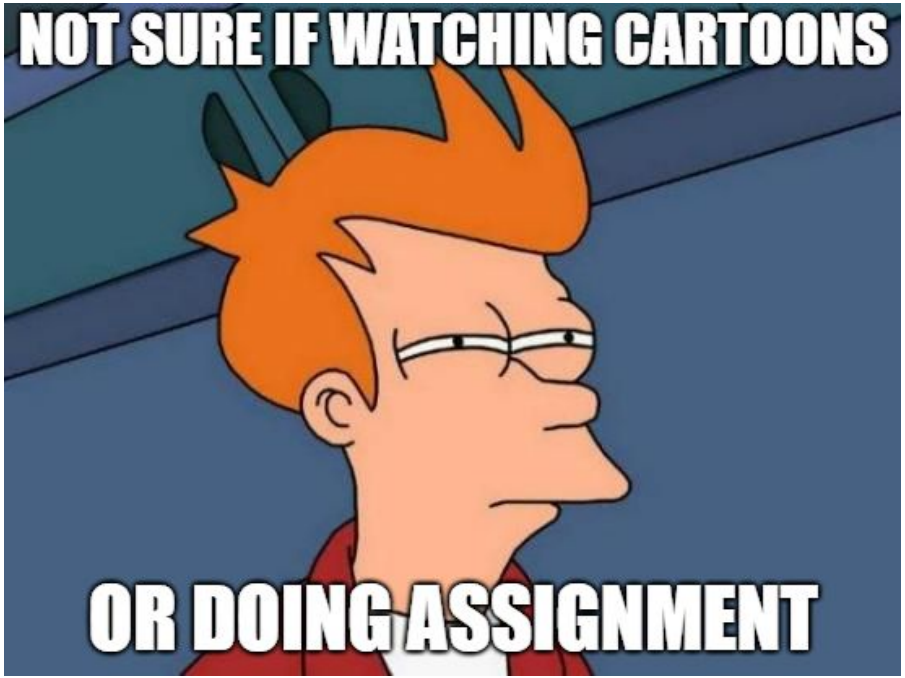
What are the six simple machines?

Simple.

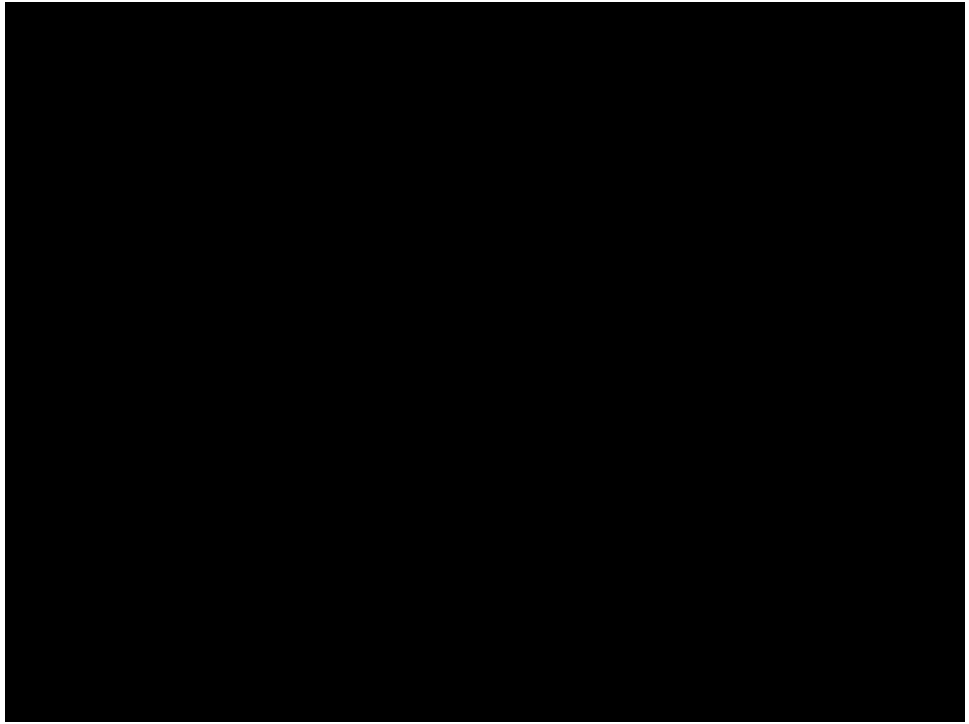
Find the simple machines

In the cartoons we are about to watch you are to find 10 example of simple machines.

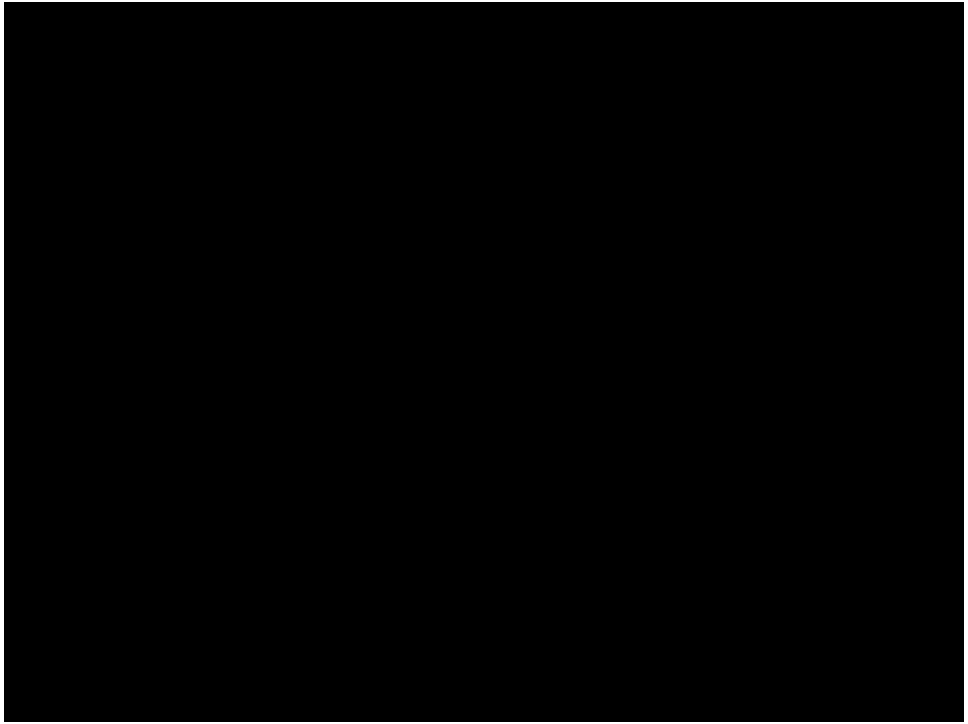
You must also include what cartoon the simple machine was found in and what it was used for. Good luck!



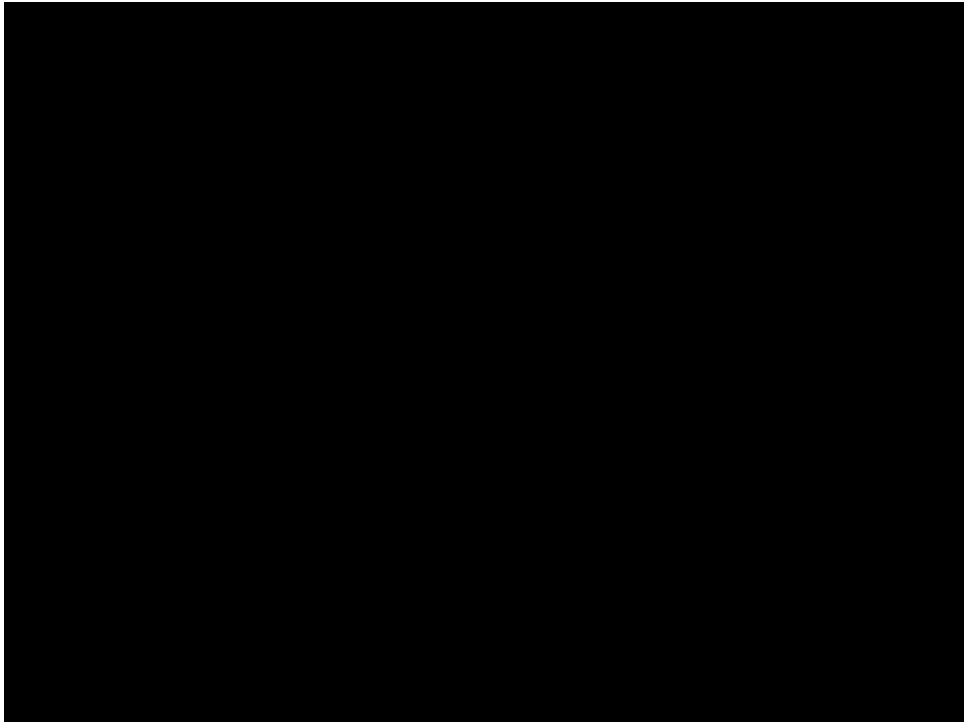
Pinky and the Brain



Recess



Road Runner Show



Classifying Simple Machines Stations

Why is beauty important?

Review!

a) What is subsystem?

b) What is an example of a complex machine?

c) What 6 simple machines may be in a complex machine?

Linkages

Because complex machines have more than one simple machine working at a time, they require a way to transfer energy from one subsystem to the next.

This requires **linkages** between subsystems. Linkages can come in many forms and can also create a mechanical advantage when used properly.

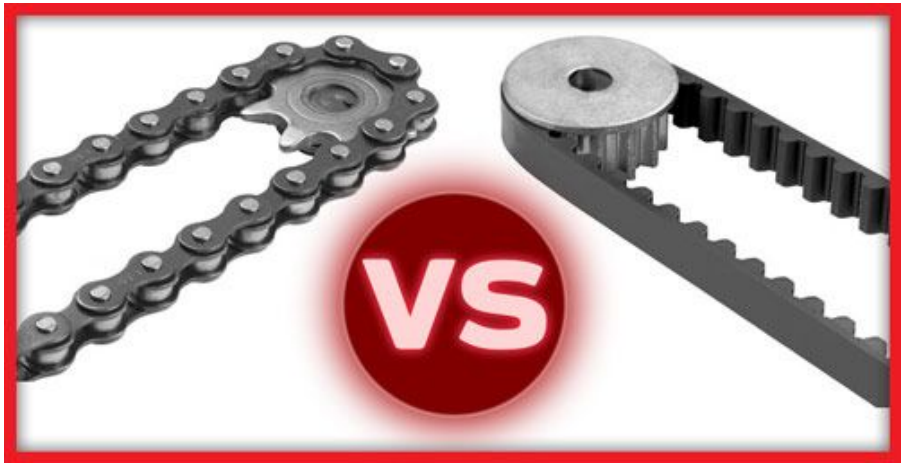
Linkages

There are several different types of linkages that transfer force from one machine to another. They are;

Belt and chain drives, drive shafts and gears.

Belt and Chain Drives

Chain drives and **belt drives** are often used in many vehicles (like bicycles, motorcycles, and automobiles) as well as other mechanical applications, including garage doors.

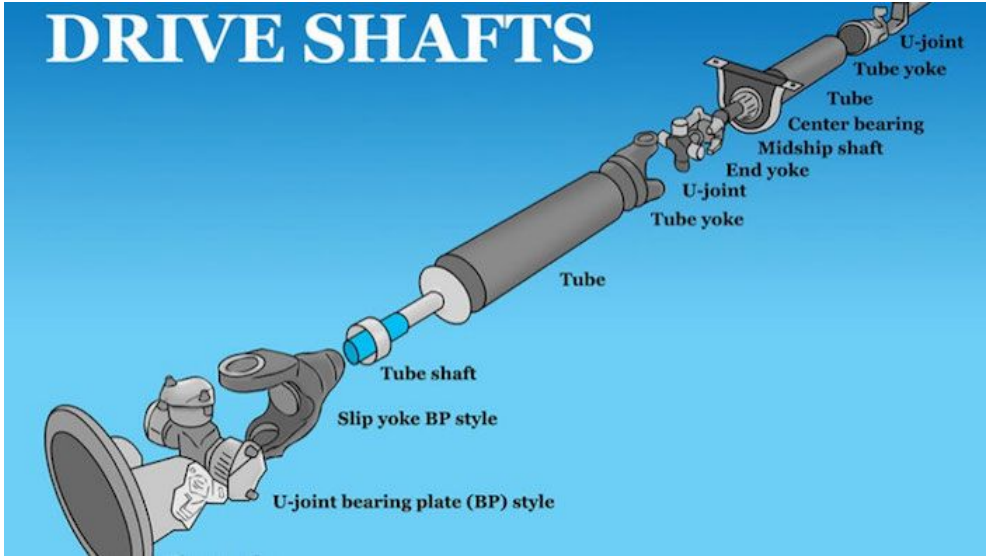


Both chain drives and belt drives are **designed as continuous and endless loops that move when the engine is running or in use**.

Drive Shafts

A **drive shaft** is a mechanical component for transmitting torque and rotation. It is usually used to connect other components of a drive train.

Drive train parts cannot be connected directly because of distance and parts require relative movement between them.



Gears

Gears are a set of wheels that have teeth that interlink.

When they rotate together, one gearwheel transfers turning motion and force to the other.

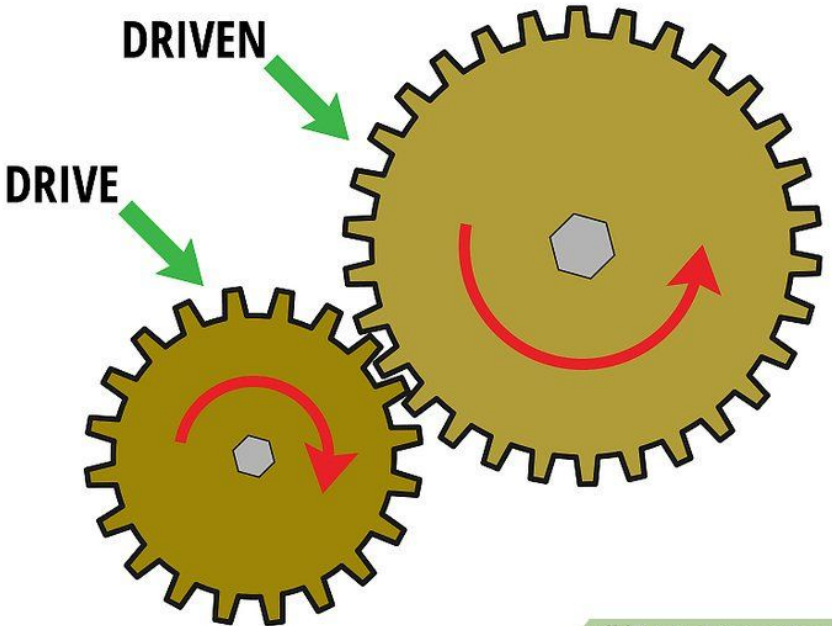
The sizes of gears can be manipulated to change the input and output force as well.


Sc

The Driving and Driven Gears

The **driving gear** is the first gear in the system and is the gear that has the energy source attached to it. The driving gear is responsible for moving the gear system.

The **driven gear** is the second gear in the system and is the gear that receives the energy from the driving gear. The driven gear is moved in the system.



Multiplying and Reducing Gears

We need to know which is the driven gear and which is the driving gear if we are to figure out if the force or speed is being reduced or multiplied.

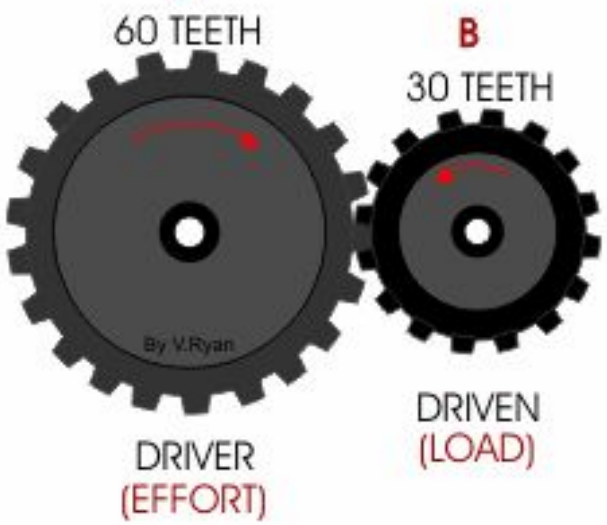
The terms **multiplying** or **reducing** gear systems are based on the output speed of the driven gear.

Multiplying Gear Systems

In a multiplying gear system the driving gear is bigger than the driven gear.

This causes the turning speed of the driven gear to be multiplied.

However, the force of the driven gear is reduced in a multiplying gear system.

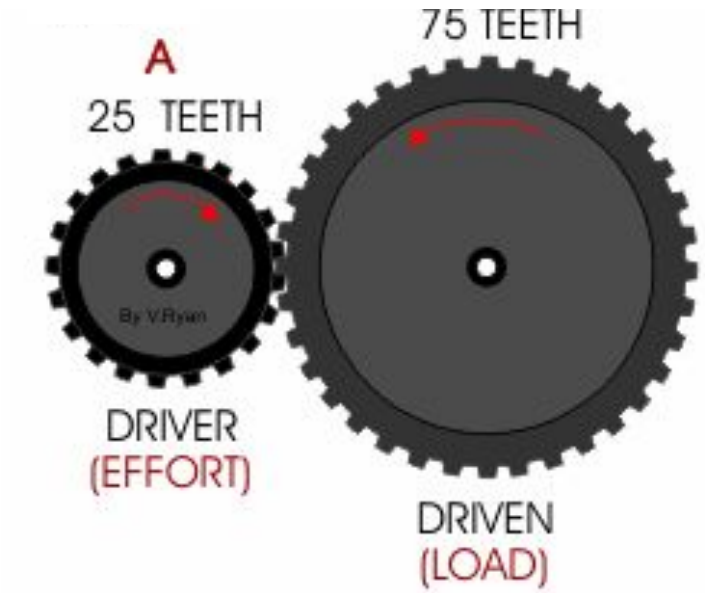


Reducing Gear System

In a reducing gear system the driving gear is smaller than the driven gear.

This causes the turning speed of the driven gear to be reduced.

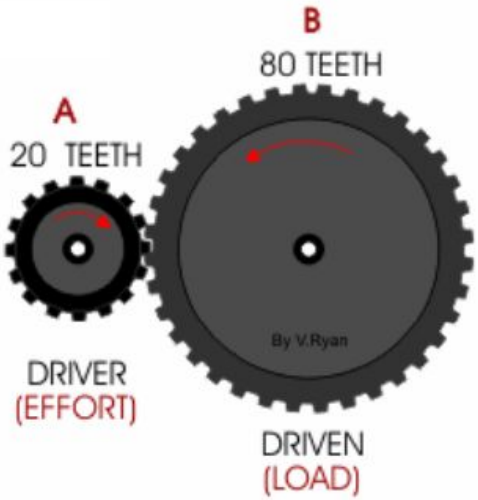
However, the force of the driven gear is increased in a reducing gear system.



Gear Ratios

The gear ratio of a gear train is found by dividing the number of teeth on the driven gear by the number of teeth on the driving gear.

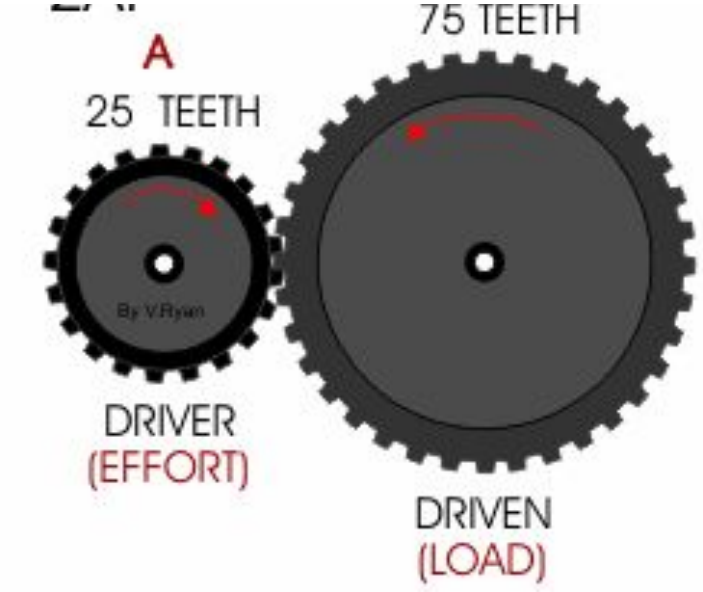
The lower the gear ratio the slower the output speed will be for that gear system.



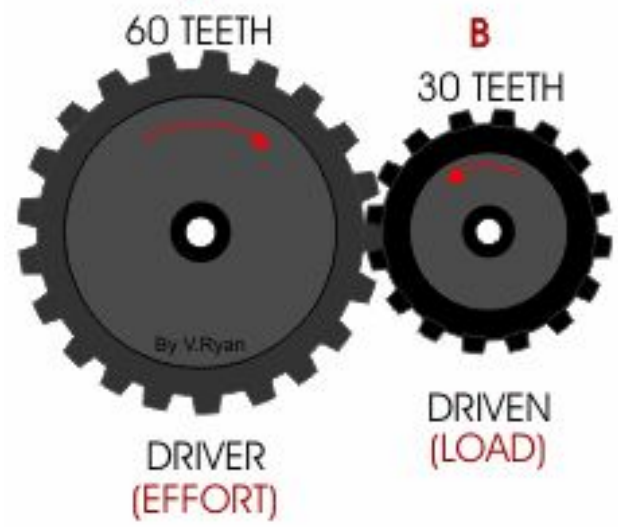
$$\frac{Driven}{Driving} = \frac{80}{20} = \frac{4}{1} \rightarrow 4:1$$

What does this mean? For every 4 rotations of the driving gear, the driven gear makes 1 rotation.

Calculate the Gear Ratio



Calculate the Gear Ratio



Mechanical Advantage

Remember: $$\text{Mechanical Advantage} = \frac{\text{Output Force}}{\text{Input Force}}$$

Newton (N) is the unit for measuring force.

One newton is equal to the amount of force exerted by Earth's gravity on a mass about 100 g

Ex// an egg

Speed Ratio

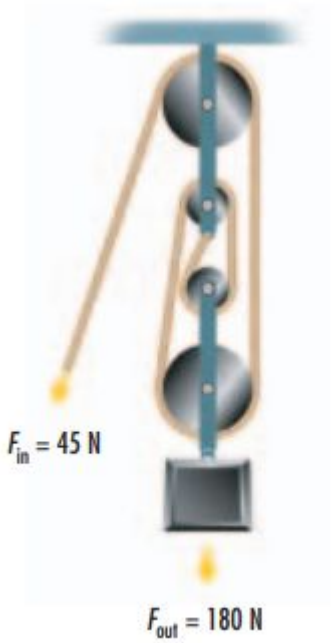
Speed measures the distance an object travels in a given amount of time.

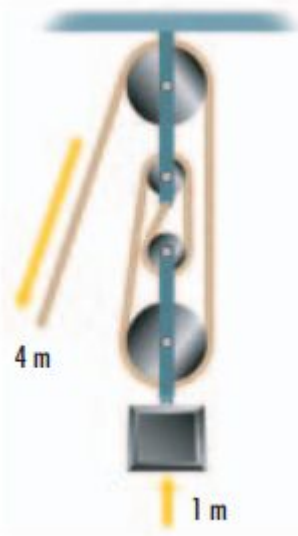
A measure of how the speed of the object is affected by a machine is called the **speed ratio.**

$$\text{Speed Ratio} = \frac{\text{Input distance}}{\text{Output distance}}$$

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

Calculate the Mechanical Advantage and the Speed Ratio





A pulley system lifts a load 5 m when two people pull the rope 10 m. What is the speed ratio of the pulley system?

The Effect of Friction

Friction is a force that opposes motion and is caused by the surface roughness of materials.

Friction can be an important factor in mechanical systems because it opposes motion. This means extra force is needed to overcome friction whenever you move an object.

Consider when you push a box up a ramp, the friction created by the box rubbing against the ramp means you have to push harder than you would if there was no friction.

Efficiency

Friction affects the mechanical advantage of a mechanical device, so it also affects its efficiency.

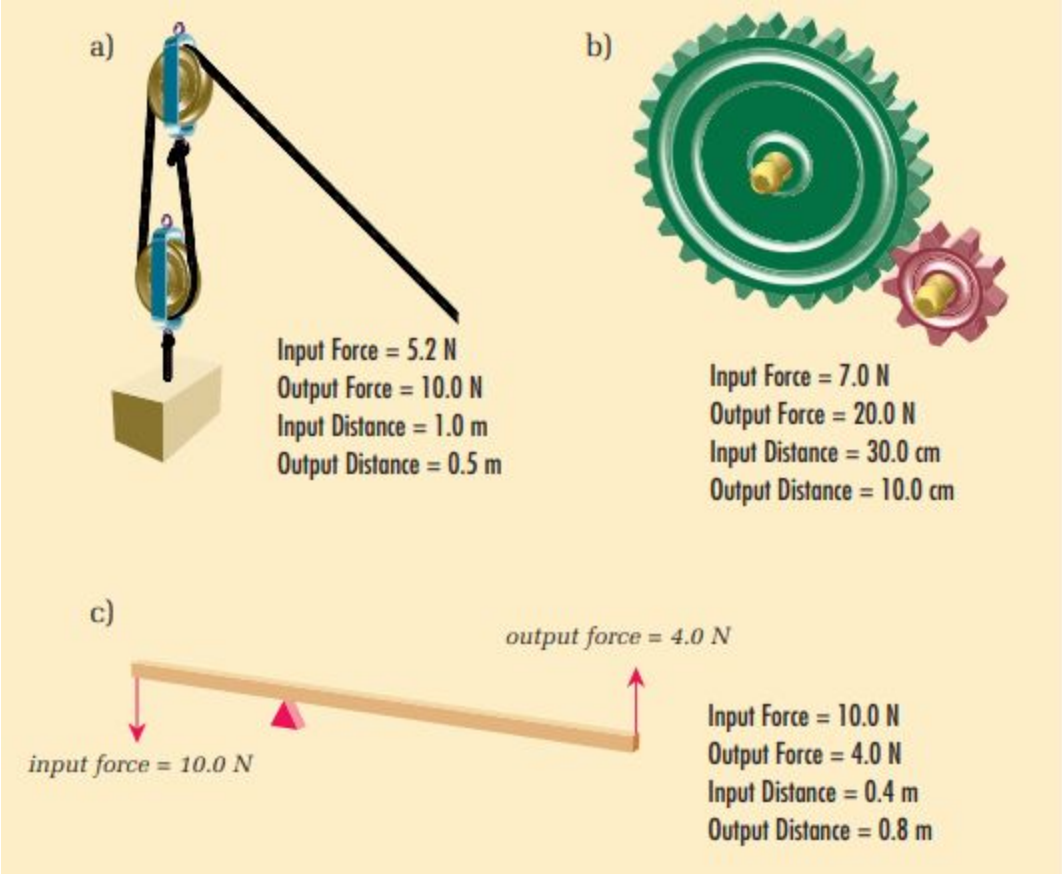
Efficiency is the measurement of how well a machine or device uses energy.

Calculating Efficiency

$$\text{Efficiency} = \frac{\text{Mechanical Advantage}}{\text{Speed ratio}} \times 100$$

Efficiency

Calculate the efficiency if a pulley has a speed ratio of 3 and a mechanical advantage of 2.


a)
Input Force = 5.2 N
Output Force = 10.0 N
Input Distance = 1.0 m
Output Distance = 0.5 m
b)
Input Force = 7.0 N
Output Force = 20.0 N
Input Distance = 30.0 cm
Output Distance = 10.0 cm
c)
output force = 4.0 N
input force = 10.0 N
Input Force = 10.0 N
Output Force = 4.0 N
Input Distance = 0.4 m
Output Distance = 0.8 m

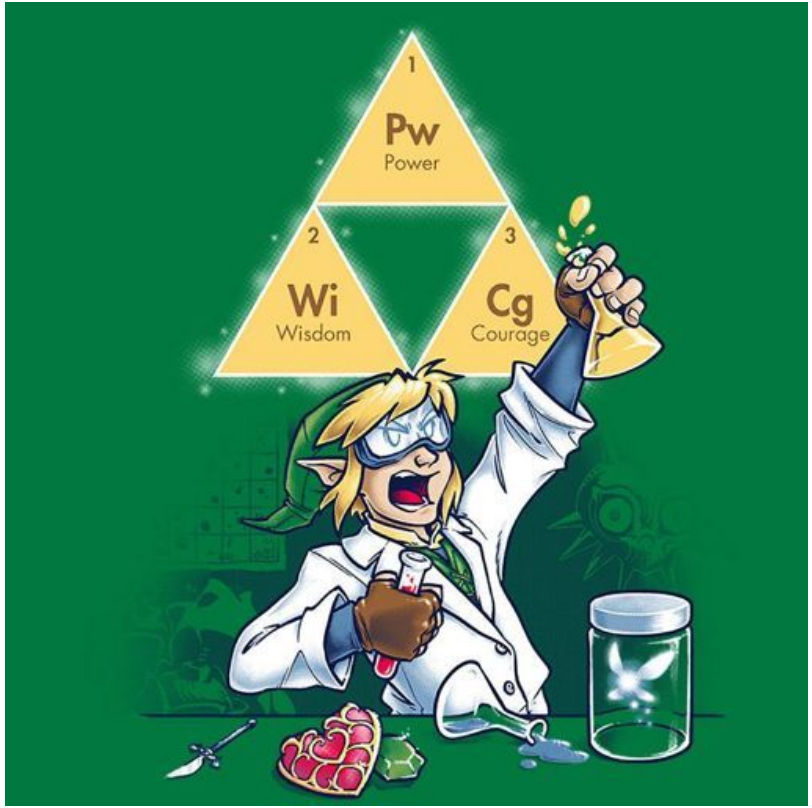
What if you only ate chips?

Review!

a) What are the three types of linkages?

b) What is the difference between a driving and a driven gear?

c) What is the trade off in multiplying and reducing gear systems?



Section 2.0 - An understanding of mechanical advantage and work helps in determining the efficiency of machines.

Learning Concepts

- Determine the mechanical advantage and the speed ratio of a mechanical device
- Modify a model mechanical system to achieve a given mechanical advantage
- Identify the reason for differences between theoretical and actual mechanical advantages
- Identify work input and output for a simple machine or mechanical system
- Describe how hydraulic pressure can create a mechanical advantage

Work

In science, **work** is defined as using a force to move an object a distance. The term work is used when both the force and the motion of the object are in the same direction.

Work is measured in Joules or Newton Metres and is calculated as;

Work = Force x Distance

Work work work ahafgeidbdveisnaidhbejdisb work work work agshifbdbksbrufudbkfbd dur dur dur

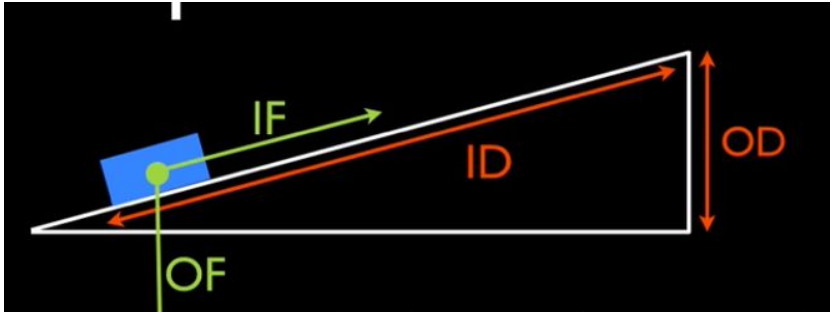
If a man pushes a concrete block 10 meters with a force of 20 N, how much work has he done?

How much work is done in pushing an object 7.0m across a floor with a force of 50 N and then pushing it back to its original position?

Work

Calculating work can be tricky when considering simple machines. It is important in this case to examine the **input force** and **distance**, as well as the **output force** and **distance**.

The output force and distance will be used to calculate the work done by the simple machine.



An inclined plane is 6.25m long and 1.25m high. The force applied by a box on the inclined plane is 200N. If the box is moved up the inclined plane, what is the work done by the inclined plane?

Mr. Clobber has to move a dishwasher into a moving truck, the deck of which is 2.5m high. He decides to use a ramp, which is 7.5 m long. The weight of the dishwasher is 900 N, and he exerts a force of 350 N as he slowly pushes the dishwasher up the ramp into the truck. What is the work done by both the ramp and Mr. Clobber?

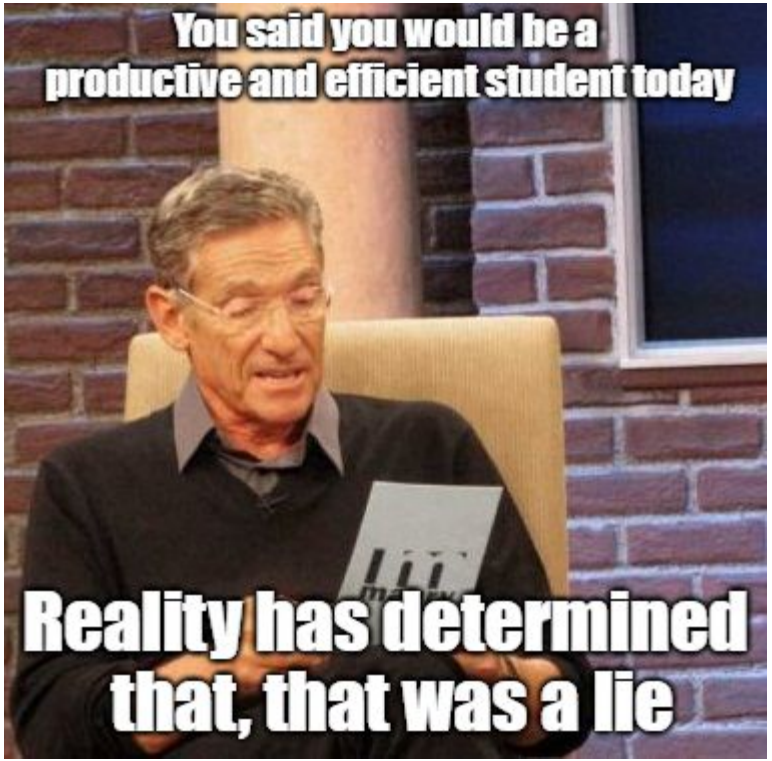
Efficiency

Efficiency is a comparison of the useful work provided by a machine or a system with the work supplied to the machine or system.

The formula for calculating efficiency is;

$$\text{Efficiency} = \frac{\text{output work (J)}}{\text{input work (J)}} \times 100\%$$

An ideal machine would have 100% efficiency, which is not possible.



You cut the lawn with a hand lawn mower. You do 250,000 J of work to move the mower. If the work done by the mower in cutting the lawn is 200,000 J, what is the efficiency of the lawnmower?

To pull a nail out of a wood board a carpenter does 1000 J of work. The hammer he uses does 835 J of work. What is the efficiency of the hammer?

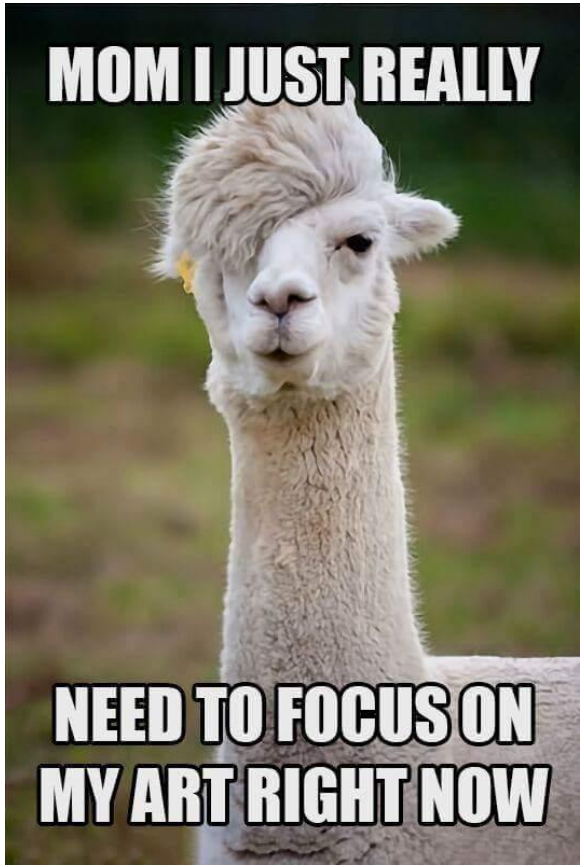
Is fat free better for you?

Review!

a) How do we calculate work?

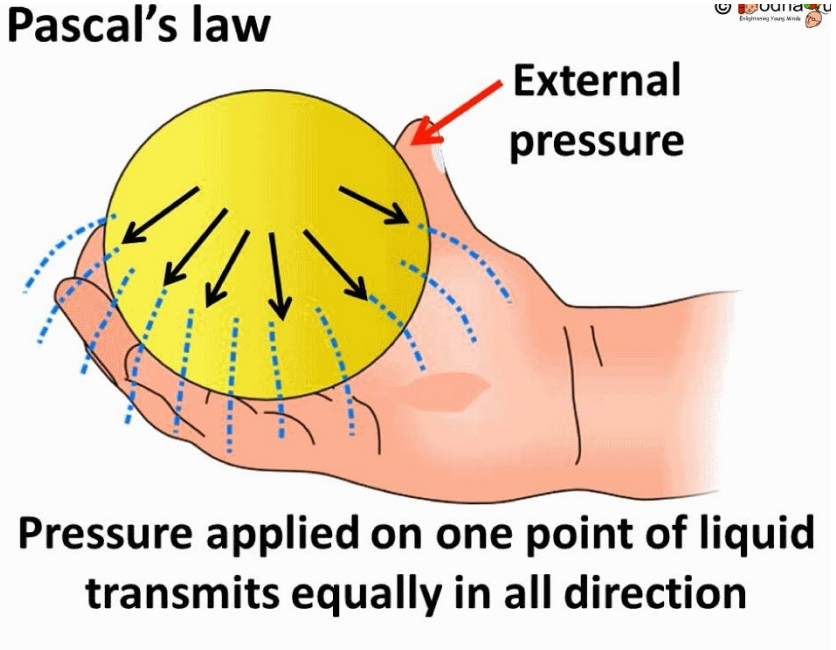
b) What is the ideal efficiency of a machine?

c) What is special about compressing a fluid?



Remember!

Pascal's Law states that when pressure is applied to a liquid in a container, the pressure and force is transmitted equally and undiminished throughout the liquid or an enclosed liquid will transmit pressure equally in all directions.

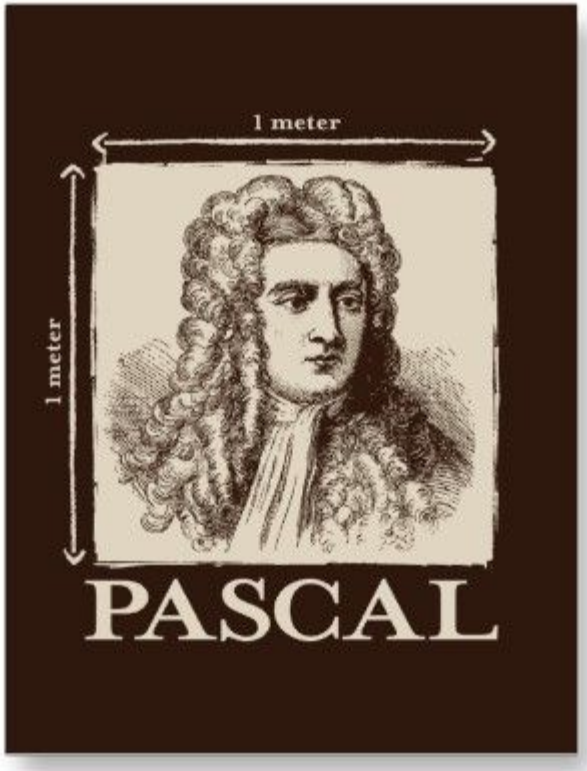


Remember!

To compress a fluid **pressure** must be applied. Pressure is the measure of the amount of force applied to a given area.

$$Pressure = \frac{Force}{Area}$$

Pressure is measured in Pascals or Newtons per metre squared.




Hydraulic lifts
Pressure in fluids

Calculating Pascal's Law

We use Pascal's Law to find the proportion needed to work hydraulics. The force and area of both pistons are proportionate to each other.

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

If the force applied to a small piston is 20N over an area of $4cm^2$. How much force would be applied by a liquid in a proportionately large piston with an area of $100cm^2$?

In a hydraulic-brake system, a force of 25N can be applied to a surface area of $5cm^2$. What force can then be exerted on each brake cylinder having an area of $100\ cm^2$?

Section 3.0 - Science, society, and the environment are all important in the development of mechanical devices and other technology.

Learning Outcomes

- Evaluate the design and function of a mechanical device in relation to efficiency and effectiveness
- Identify the impacts of a mechanical device on humans and the environment
- Develop and apply criteria for evaluating a mechanical device
- Describe how the following factors affect technological development: advances in science, trial and error, and changes in society and the environment

Evaluating Mechanical Devices

Inventors evaluate mechanical devices to find ways to make them easier to use or to find other ways of doing the same task.

If you were buying a new bike, what features would you want? With your partner, make a list.

Evaluating Mechanical Devices

If you were buying a new bike, what features would you want? With your partner, make a list.

All the features you listed are your CRITERIA. That is, the features one would consider when deciding if a design would fit your needs.

Efficiency

How quickly and easily it helps you do a task.

What is an example of a device that is efficient?

Function and Design

Function is what the device is supposed to do while the design is the physical form of the device that makes it useable?

What do scientists have to consider first, function or design?

Considering the Environment

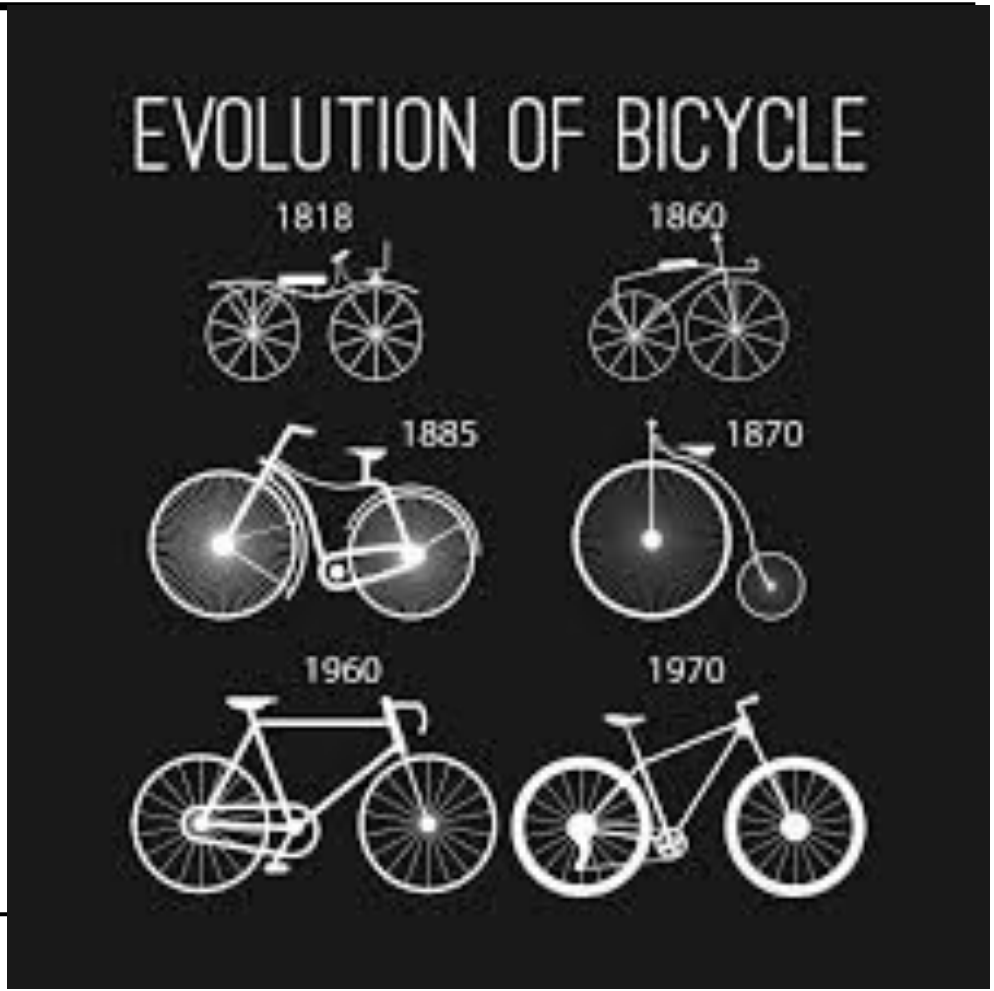
What effect does the device have on the environment?

For example, spikes on a mountain bike may make the bike more effective in climbing slopes. However, this would tear up soil and plants more so than an ordinary bike.

How about cars?

Evolution of Devices

Since we are constantly looking for newer and better, devices are constantly evolving.



1934-1963+

In 1909, a Montana brewer suggested that beer be put in cans. It wasn't until Prohibition lifted a little in 1933 that Kruger's was allowed to fill 2,000 cans, yet sold none. On January 24, 1935, Kruger Cream Ale was sold in Richmond, VA. Cans contained 12 fluid oz., a standard kept to this day. On the side of cans were instructions for how to use a church key opener.

1962-1965

Zip or Tab Top pull tabs were first introduced in 1962. Schlitz was the first nation-wide brand to feature a "snap top." Ermal "Ernie" Fraze is credited with the patent. By August, 1963, 65 brands used this new design. In 1964, Continental Can introduced the "U-tab." In 1965, the first "ring pull" tab can was marketed. Ring pull tabs were used until 1975.

Maxwell, D. R. S. (January-10, 1992). Beer Cans: A Guide for the Archaeologist. Historical Archaeology, 27, 1, 90-111

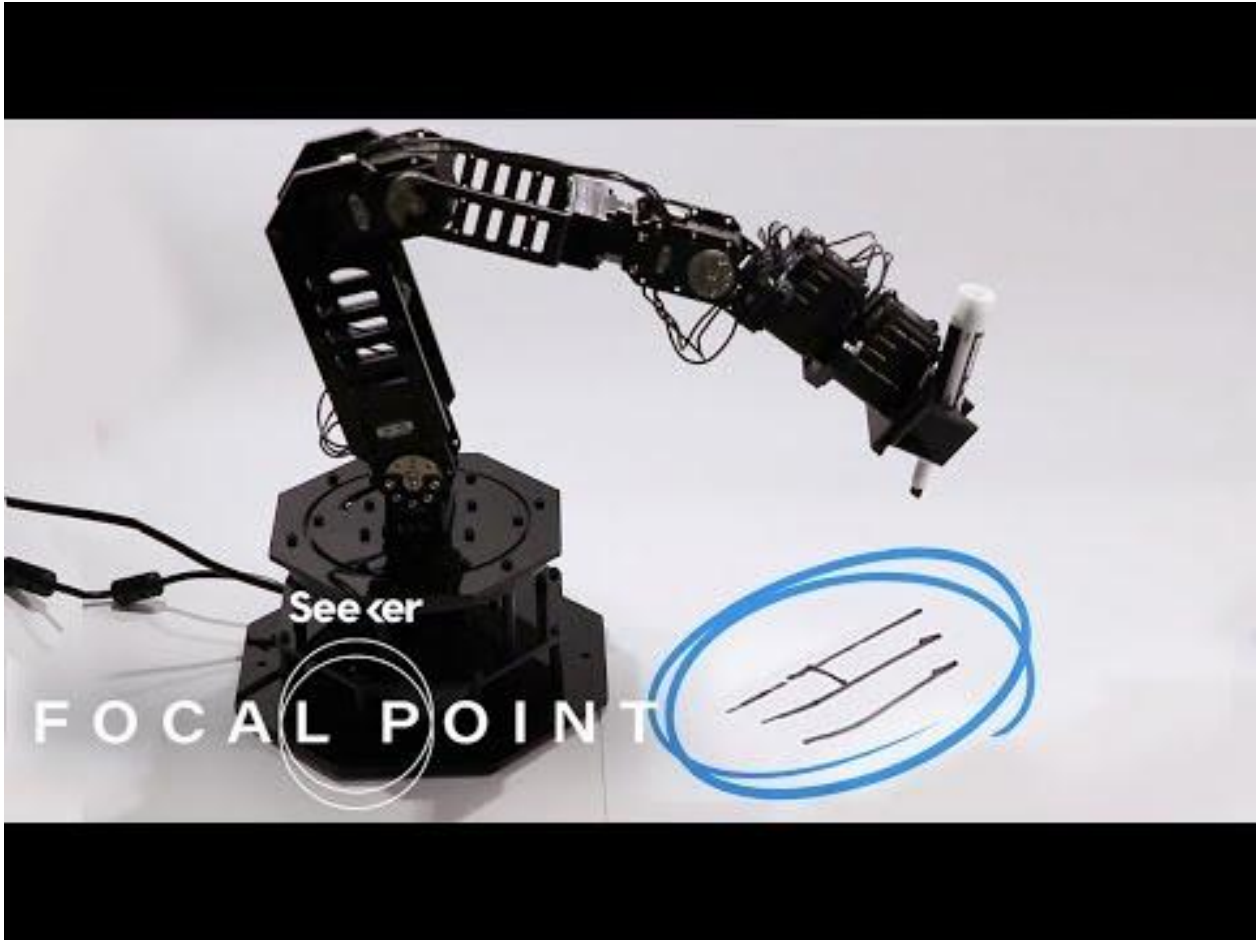
1965-1975

Early tabs were quite sharp, and sometimes cut fingers or toes when stepped on at the beach or while camping. In 1964, the American Can Company introduced a tab without sharp edges. "Smile beads" were also introduced, claiming that the raised edge around the opening prevented spillage. Two small raised beads used to align the tab looked like eyes to some.

1975-2015

When the Sta-Tab launched in 1975, on Falls City beer, there was period of consumer testing and education--rather like the opening instructions printed on flat-top cans from 1934 to the early 1960s. From a waste point of view, the years after "the stay-on-tabs alone amounted to over 4 million tons of aluminum that was recovered and recycled rather than discarded."

Changes in Society Result in New Technology


Seeker
FOCAL POINT