Crazy Contraptions
Activity Guide

EE

Revision 3.0

1. Ball rolls down ramps onto lever
2. Lever pivots and tosses dime
3. Dime lands in funnel and falls onto 2nd lever
4. Ramp tilts and car rolls down it into cup
5. Cup pulls string running around pulleys and turns wheel and axle
6. Wheel and axle winds string
7. String pulls wedge
8. Wedge releases lever
9. Lever pivots and raises flag

Build a jaw dropping, innovative, Rube Goldburg style machine

TeacherGeek.com

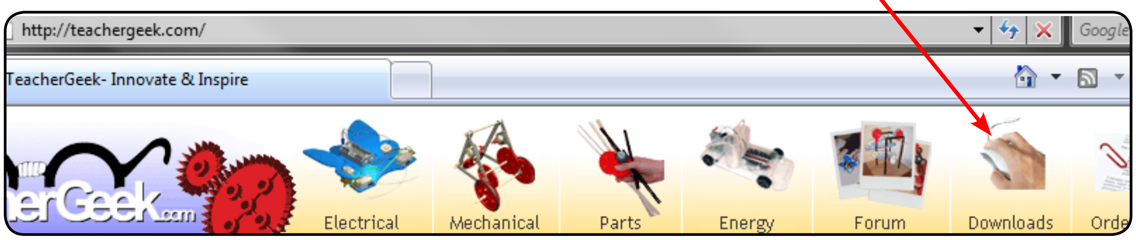
The Guide

This guide will take you through the process of creating a crazy contraption (a machine that performs a simple task in an overly complex way).

Throughout the process, you will build a portfolio documenting how you created your contraption.

The Design Portfolio

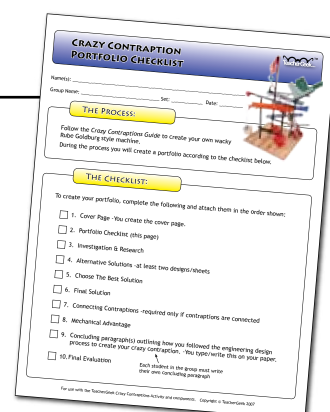
The Activity Guide (this document) is designed to be reused. Your work (drawings and writing) will go into your portfolio. The student portfolio document can be downloaded at TeacherGeek.com:



Your First Detour

Freak-out!!! Just kidding...

The detour sign tells you when you need to complete a page in your student portfolio.

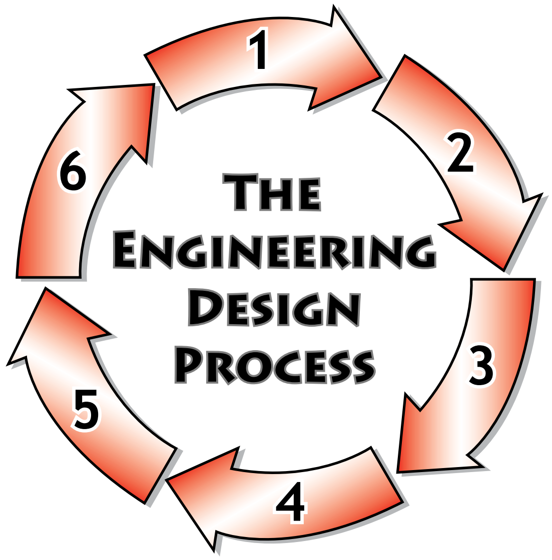


Make sure you have your student portfolio packet. Put your information on the cover and keep it safe.

THE ENGINEERING DESIGN PROCESS

The Engineering Design Process is a series of steps that engineers use to guide them as they solve problems. You will use the Engineering Design Process to help you create your Crazy Contraption.

1. Identify the Problem
2. Investigation and Research
3. Generate Alternative Solutions
4. Choose the Best Solution
5. Prototyping
6. Test and Evaluate



SYSTEMS AND SUBSYSTEMS

Your contraption will be made from many subsystems that link together to form a system.

Something you never wanted to know...

Mechanical systems are referred to as machines. Machines are made up of subsystems called mechanisms. A machine is a combination of two or more mechanisms that work together to perform a task.

SUBSYSTEM (MECHANISM)

A mechanism or group of mechanisms that fits into a larger system (machine).

SYSTEM (MACHINE)

A group of connected parts that work together to accomplish a task.

STEP 1

THE ENGINEERING DESIGN PROCESS

IDENTIFY THE PROBLEM

About this step: The problem statement provides information that justifies the need for a solution to a problem. The design brief helps us focus on the problem and gives guidelines that we will adhere to while designing a solution. These guidelines are referred to as Design Constraints.

PROBLEM STATEMENT

Design and build a machine that performs a simple task through an extremely complex process.

☐ Option 1: Contraptions will function independent of each other.

Contraption 1 | Contraption 2 | Contraption 3 | Contraption 4

Don't stop at 4. Create as many contraptions as you can.
• • •

Each contraption must perform a simple task such as popping a balloon, lighting a light bulb, cracking an egg, raising a flag...

☐ Option 2: Contraptions will be connected in series. The first contraption triggers the second, which triggers the third and so forth until the last contraption is reached. The last contraption must perform a simple task.

System

Contraption 1 → Contraption 2 → Contraption 3 → Contraption 4 →

Subsystem

Don't stop at 4. Create as many contraptions as you can.

The last contraption must perform a simple task such as popping a balloon, lighting a light bulb, cracking an egg, raising a flag...

Check out the next page for your design brief and evaluation criteria.

DESIGN BRIEF

The contraption must:

1. transfer energy through a series of mechanisms. Each mechanism will link with the next mechanism to transfer energy from start to finish.
2. operate completely on its own, once started.
3. fit into the area directly above its 12” x 12” base, other than any components designated to trigger another contraption. There is no limit to the height of your subsystem, but it must be free-standing.
4. be constructed from the parts specified on page 2, or other teacher approved materials (from the classroom or home).
5. use 4 or more simple machines (the more simple machines, the better).
6. take more than 4 seconds to transfer energy through its system.
7. not involve any living creatures (other than a person to start it).
8. be safe (it may not contain potentially hazardous items or operate in a hazardous way).
9. not damage other contraptions.

EVALUATION CRITERIA

- **Design Brief**
    - The machine should fit the design brief (look above).
- **Function**
    - The machine should complete its task with no human intervention.
    - The machine should be reliable.
- **Creativity**
    - The machine’s steps should be innovative.
    - Materials/Components should be used in unique ways.
- **Complexity**
    - Your machine should have at least 4 steps using at least 4 different simple machines.
    - Five points will be awarded for each additional step beyond 4.
    - All steps should be unique from each other and of reasonable complexity.
- **Participation & Teamwork**
    - Team members must actively participate throughout the activity.
- **Mechanical Advantage**
    - Mechanical advantage should be calculated for at least 2 of the simple machines in the contraption.
- **Portfolio**
    - A design portfolio must be created for your contraption
        - Requirements are listed in the student portfolio document.

STEP 2 — THE ENGINEERING DESIGN PROCESS
INVESTIGATION AND RESEARCH

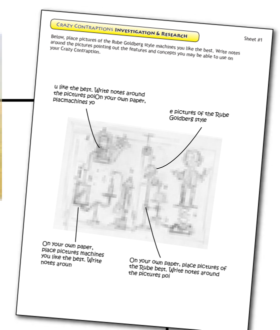
Engineers and designers rarely start from scratch when solving a problem. They research existing inventions and gather information that could help them find a new solution.

RESEARCH WHAT?

During this step you will research:

- Existing Contraptions
- Simple Machines & Mechanisms
- Mechanical Advantage
- Parts for Your Contraption

INVESTIGATE & RESEARCH CONTRAPTIONS



Thousands of Rube Goldberg style machines have been created. Your job is to research some of them.

On the "Investigation & Research" pages of your design portfolio, place pictures of the Rube Goldberg style machines you like best. Write notes around the pictures pointing out the features and concepts you may be able to use on your Crazy Contraption.

INVESTIGATE & RESEARCH MACHINES

A machine is a device that helps make work easier by:

- transferring a force from one place to another
- changing the direction of a force
- changing the amount, distance and speed of a force

How can a pipe wrench turn 50lbs of force into 600lbs of force. It trades force for distance. See how on the following pages.

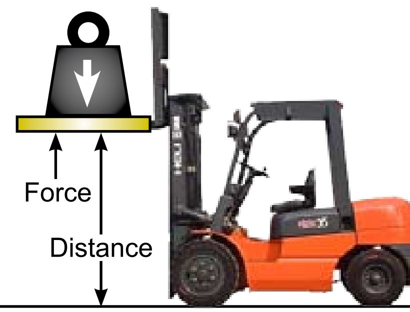
WORK

The scientific definition of work: Using a force to move an object a distance.

$$\text{Work} = \text{Force} \cdot \text{Distance}$$

Force: The pull or the push on an object, resulting in its movement.

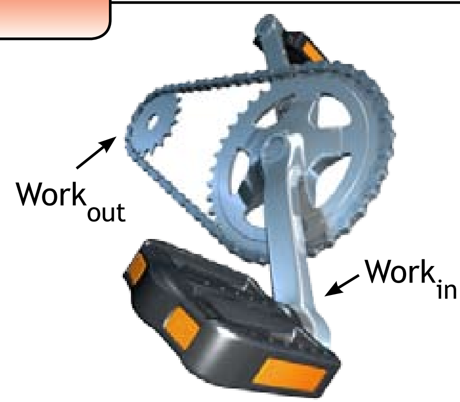
Distance: The amount the object moves.



MECHANICAL ADVANTAGE

Mechanical Advantage is the relationship between the input force (work in) and the output force (work out).

$$\text{Work}_{in} = \text{Work}_{out}$$



Work equals force times distance, so we can say...

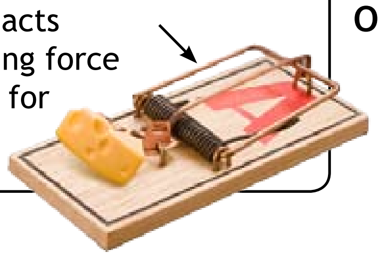
$$\text{Force}_{in} \cdot \text{Distance}_{in} = \text{Force}_{out} \cdot \text{Distance}_{out}$$

- Force_{in}: Input Force. Also called "Effort"
- Distance_{in}: The distance over which the input force is applied
- Force_{out}: Output Force
- Distance_{out}: The distance over which the output force is applied

$$\text{Mechanical Advantage} = \frac{\text{Distance}_{in}}{\text{Distance}_{out}} = \frac{\text{Force}_{out}}{\text{Force}_{in}}$$

FORCE FOR DISTANCE

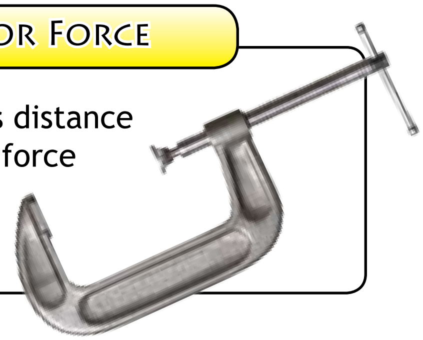
The "hammer" acts as a lever, trading force from the spring for distance.



or

DISTANCE FOR FORCE

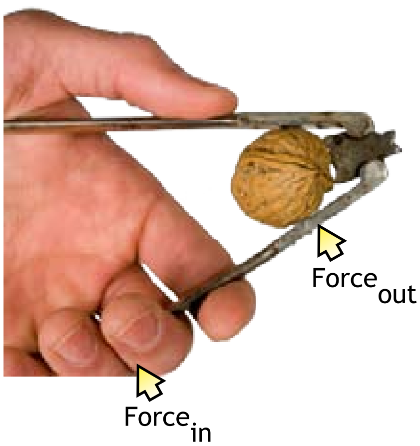
The screw trades distance (revolutions) for force to clamp.

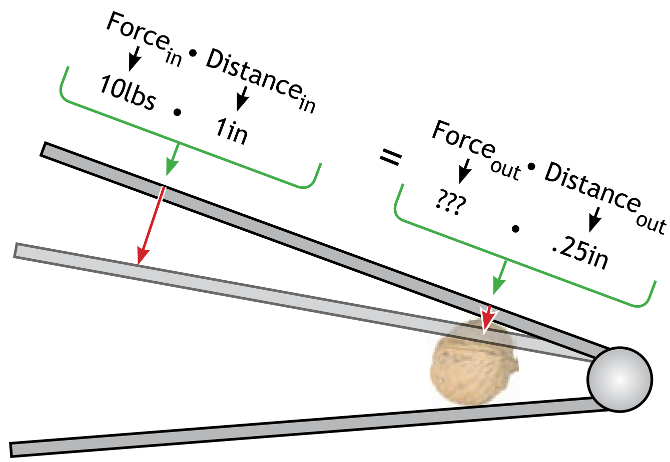


MECHANICAL ADVANTAGE (CONTINUED)

THAT'S NUTS...

How does a nutcracker use mechanical advantage?





① $$\text{Mechanical Advantage} = \frac{\text{Distance}_{in}}{\text{Distance}_{out}} = \frac{\text{Force}_{out}}{\text{Force}_{in}}$$

$$\text{Mechanical Advantage} = \frac{1\text{in}}{.25\text{in}} = \frac{\text{Force}_{out}}{10\text{lbs}}$$

② Solve for: Force_{out} $\quad \text{Force}_{out} = 40\text{lbs}$

We can use the proportions $\frac{\text{Distance}_{in}}{\text{Distance}_{out}}$ or $\frac{\text{Force}_{out}}{\text{Force}_{in}}$ to find mechanical advantage.

③ $$\text{Mechanical Advantage} = \frac{40\text{lbs}}{10\text{lbs}}$$

Mechanical Advantage = 4:1

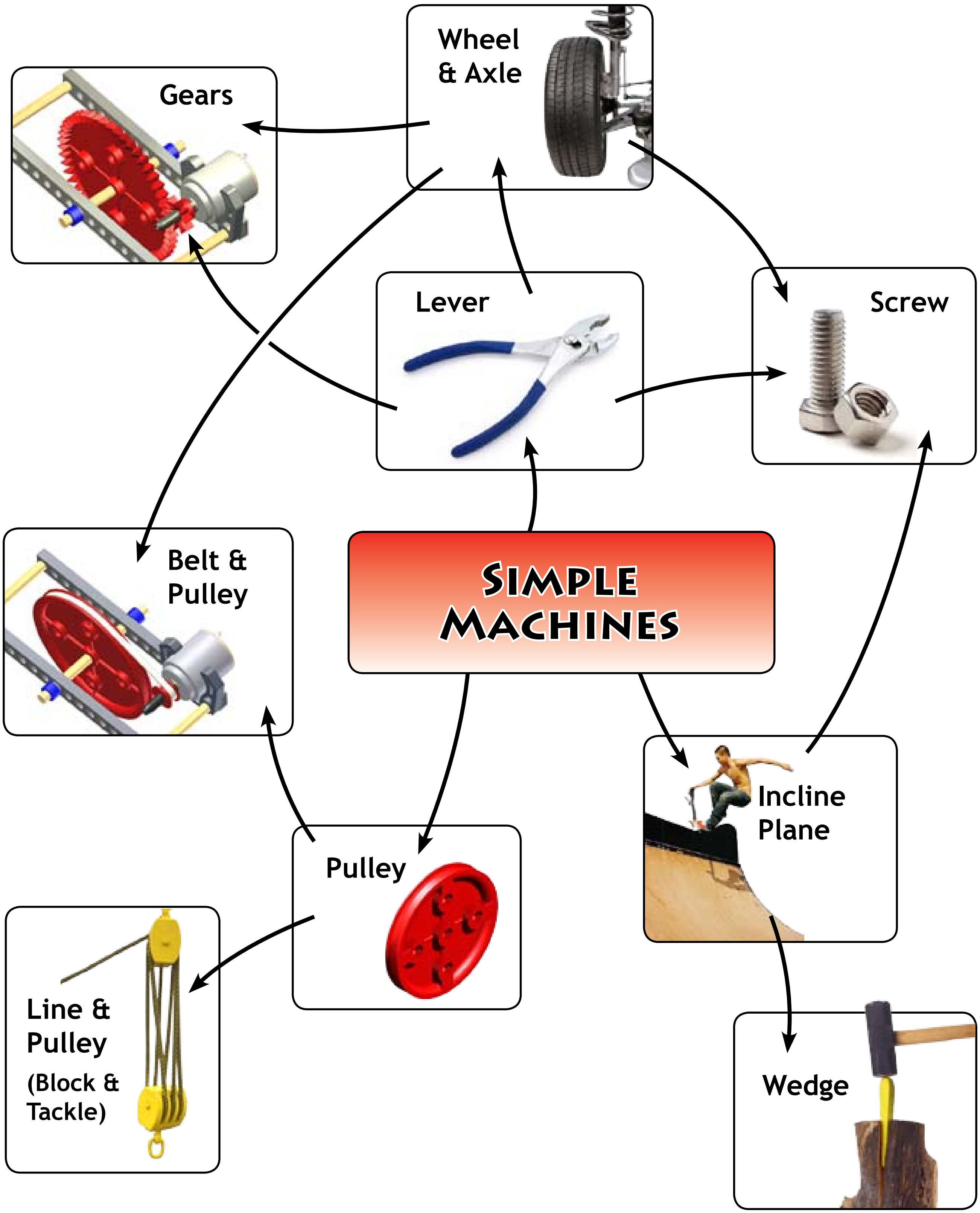
What does this mean?

- For every 1lb of input force, you will get 4lbs of output force.
- For every 1in of input distance, you will get a 1/4in output distance.

IDEAL VS. ACTUAL MECHANICAL ADVANTAGE

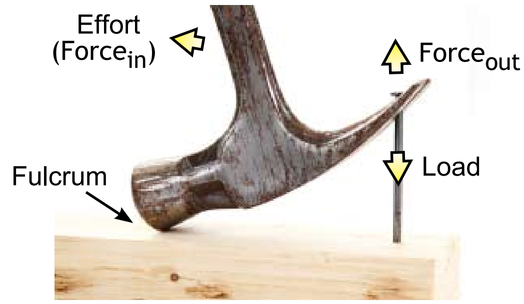
Above we calculated the ideal mechanical advantage. Not all forces were considered. We didn't account for friction losses or the mass of the machine.

We could find actual mechanical advantage by measuring the input and output forces. The measurements would show how its mechanical advantage is reduced by energy lost.


Wheel & Axle
Gears
Lever
Screw
Belt & Pulley
SIMPLE MACHINES
Incline Plane
Pulley
Line & Pulley (Block & Tackle)
Wedge

Levers

A lever consists of a rigid bar pivoted on a “fulcrum” (fixed point). It is used to move a load.



The “load” is the force that opposes the Force$_{out}$

Types of Levers

Ideal Mechanical Advantage

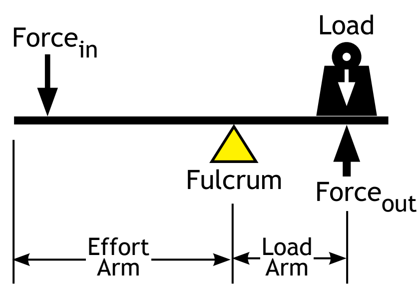
Also known as the “effort” →

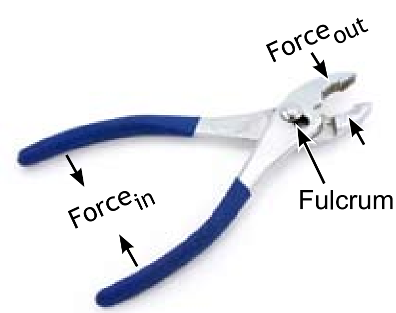
$$\frac{Force_{out}}{Force_{in}} = \frac{\text{Effort Arm Length}}{\text{Load Arm Length}} = \frac{Distance_{in}}{Distance_{out}}$$

Class One Lever

The fulcrum is located between the effort and the load.

1st class levers always change the direction of force.

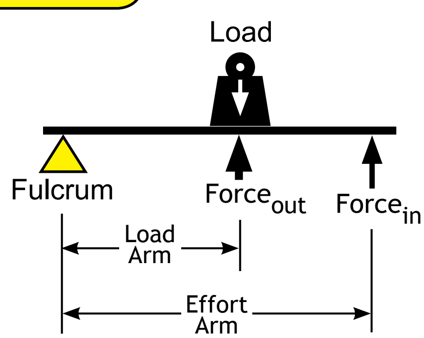


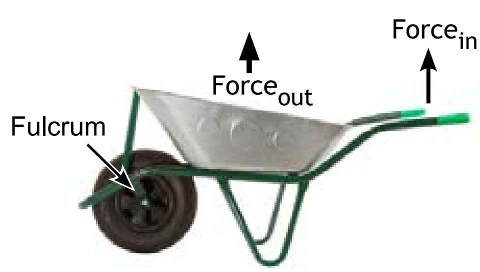


Class Two Lever

The load is located between the fulcrum and the effort.

A 2nd class lever does not change the direction of force.



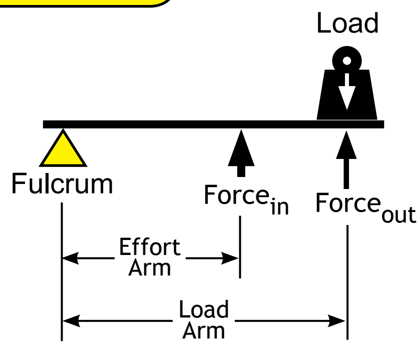


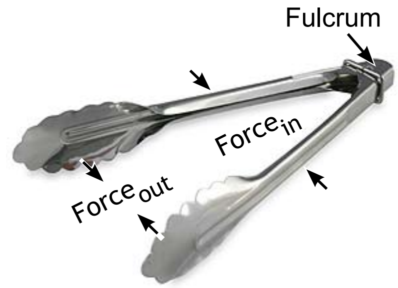
It causes the load to increase in force, but decrease in speed and distance.

Types of Levers (continued)

Class Three Lever

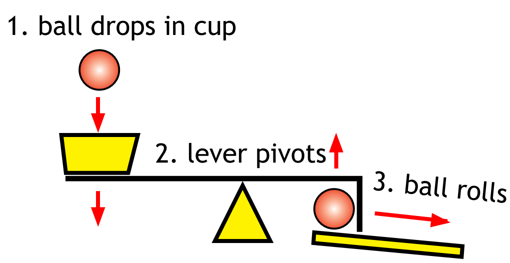
The effort is located between the fulcrum and the load.

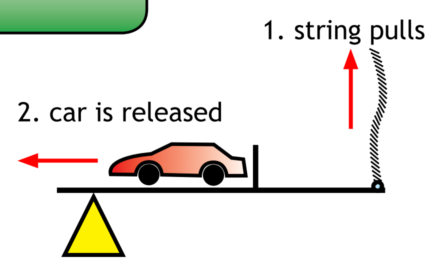


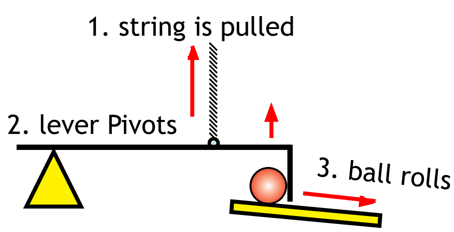


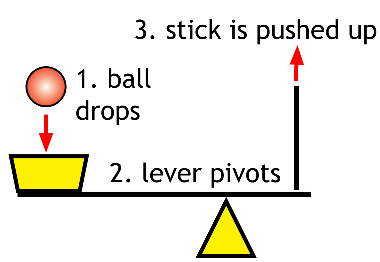
A 2nd class lever does not change the direction of force.
It causes the load to decrease in force but gain speed and distance.

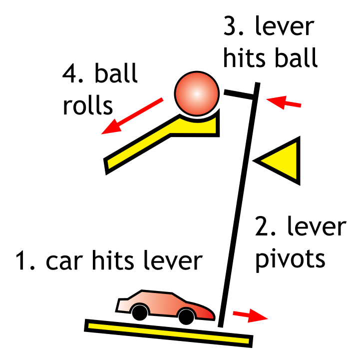
Mechanisms with Levers





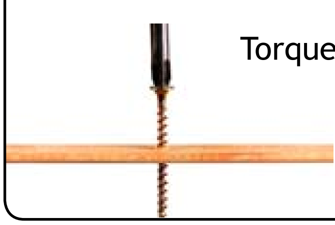






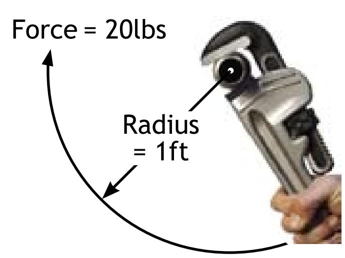
What is Torque?

Torque is a turning or twisting force.



Torque = Force • Lever Arm

(The distance of the Force$_{in}$ from the axis)



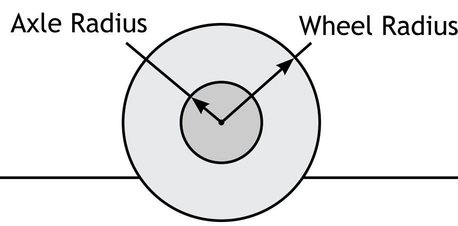
What is the torque applied to the pipe?

Torque = 1ft • 20lbs

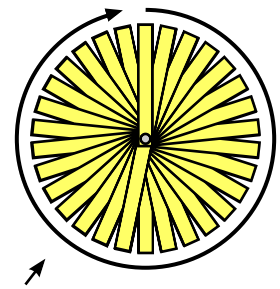
Torque = 20ft•lbs (20 foot-pounds)

WHEEL & AXLE

IDEAL MECHANICAL ADVANTAGE



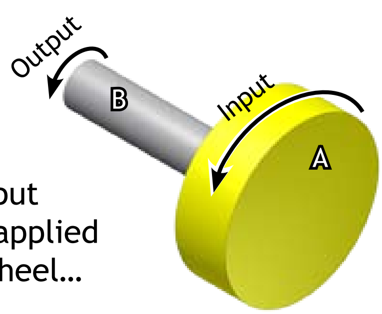
$$\frac{\text{Torque}_{out}}{\text{Torque}_{in}} = \frac{\text{Input Radius}}{\text{Output Radius}}$$



A wheel works like a lever revolving around an axis.

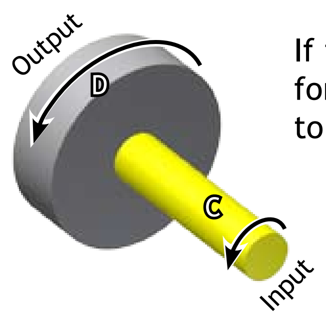
THE WHEEL & AXLE

Mechanical Advantage: The ratio between the input and output radius.



If the input force is applied to the wheel...

	Wheel A (Input)	Axle B (Output)
Circumference (distance the force is applied)	Smaller	Larger
Torque	More	Less

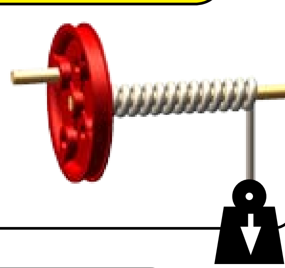


If the input force is applied to the axle...

	Axle C (Input)	Wheel D (Output)
Circumference (distance the force is applied)	Smaller	Larger
Torque	More	Less

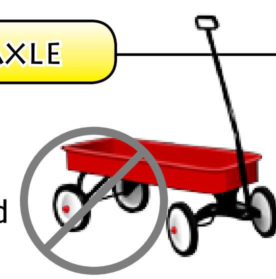
THE WINDLASS (WINCH)

A windlass is really a wheel and axle (with a cable wrapped around the axle).



NOT A WHEEL & AXLE

To be a "wheel and axle," the wheel and axle must be connected and turn together.



WHAT IS RPM?

RPM = Revolutions Per Minute

(The number of times something spins around in a minute)

Cars have RPM guages

Pulleys

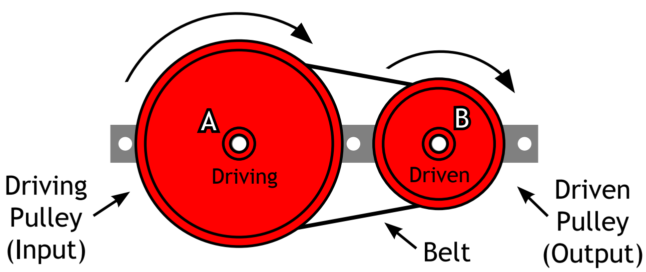
A pulley is a wheel with a groove around its outer circumference. A line or belt normally sits within the groove. Pulleys are used to change the direction of applied force (effort), transmit rotational motion, and/or create a mechanical advantage.

Pulley Systems: Pulleys & Belts

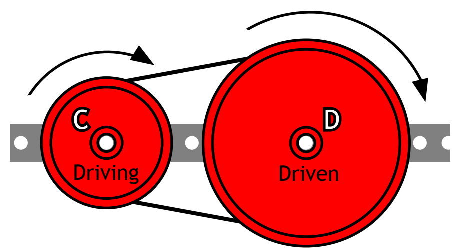
Ideal Mechanical Advantage =

$$\frac{\text{Torque}_{out}}{\text{Torque}_{in}} = \frac{\text{Input Pulley Radius}}{\text{Output Pulley Radius}} = \frac{\text{Driving Pulley RPM (Distance}_{in}\text{)}}{\text{Driven Pulley RPM (Distance}_{out}\text{)}}$$

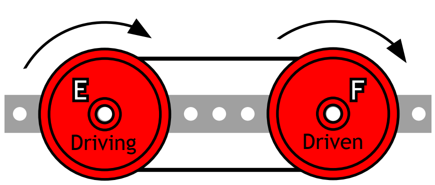
The following examples illustrate torque calculated at the pulley axles.



	Axle A (Driving)	Axle B (Driven)
RPM	Less	More
Torque	More	Less

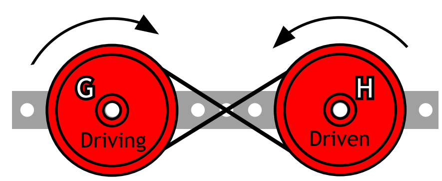


	Axle C (Driving)	Axle D (Driven)
RPM	More	Less
Torque	Less	More



	Axle E (Driving)	Axle F (Driven)
RPM	Same	Same
Torque	Same	Same

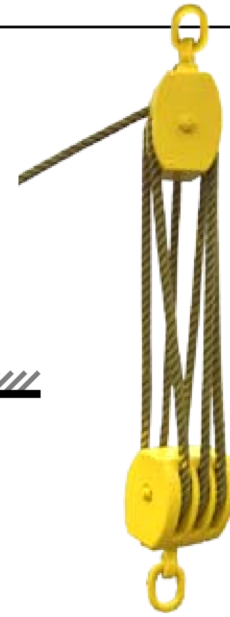
This pulley system transfers power, but has no mechanical advantage.



	Axle G (Driving)	Axle H (Driven)
RPM	Same	Same
Torque	Same	Same

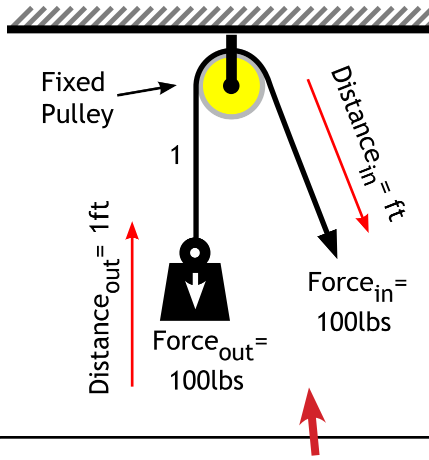
This pulley system transfers power, but has no mechanical advantage. Axle G and Axle H turn in opposing directions.

Pulley Systems: The Block & Tackle



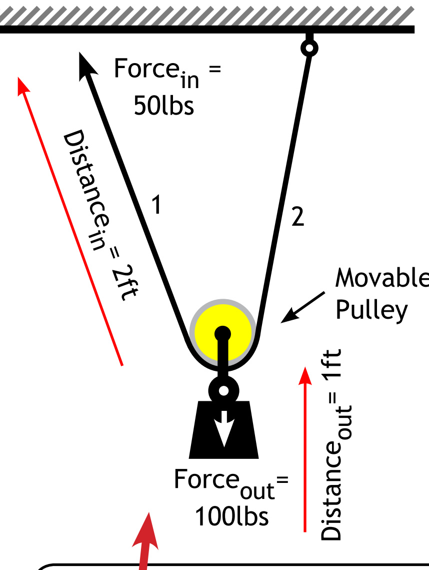
Ideal Mechanical Advantage of pulley systems can be calculated by counting the number of lines supporting the load.

$$\frac{\text{\# of Lines Supporting the Load}}{1} = \frac{Force_{out}}{Force_{in}} = \frac{Distance_{in}}{Distance_{out}}$$

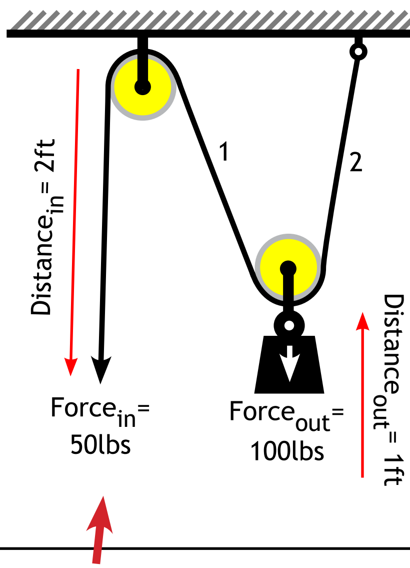


1 Line Supporting the Load = Mechanical Advantage of 1 (no mechanical advantage)

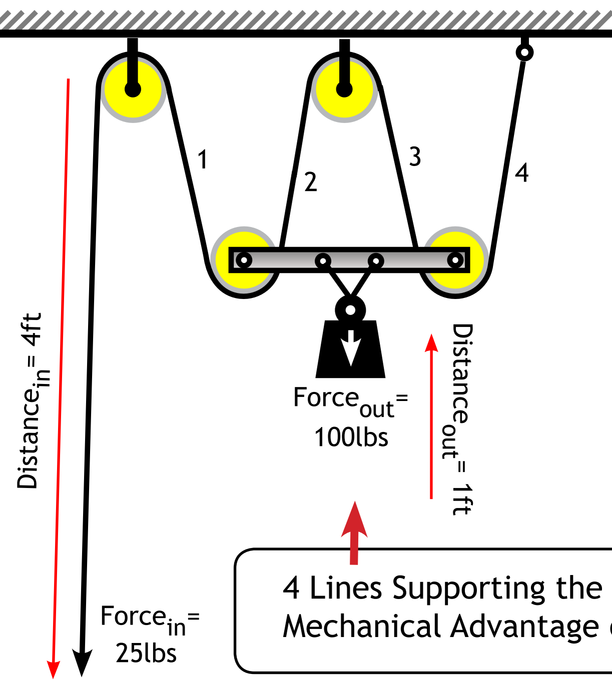
The fixed pulley changes the direction the effort is applied.



2 Lines Supporting the Load = Mechanical Advantage of 2

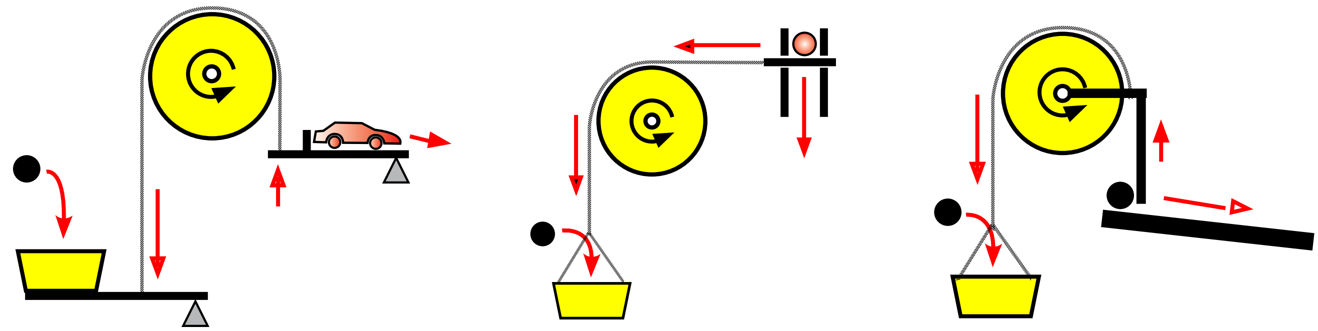


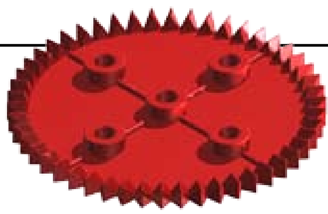
2 Lines Supporting the Load = Mechanical Advantage of 2



4 Lines Supporting the Load = Mechanical Advantage of 4

Mechanisms with Pulleys





Gears

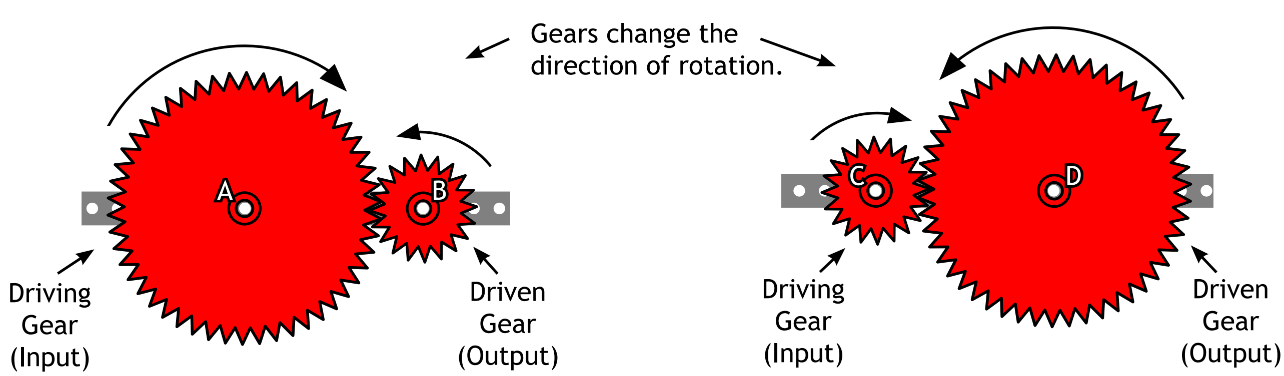
A gear is a wheel with evenly spaced teeth around its perimeter.

The teeth on multiple gears can mesh to form a gear train. Gear trains (meshing gears) can transmit force, create a mechanical advantage, or change the direction of force.

Ideal Mechanical Advantage

$$\frac{\text{Torque}_{out}}{\text{Torque}_{in}} = \frac{\text{\# of Teeth on the Driving Gear}}{\text{\# of Teeth on the Driven Gear}} = \frac{\text{Driving Gear RPM (Distance}_{in}\text{)}}{\text{Driven Gear RPM (Distance}_{out}\text{)}}$$

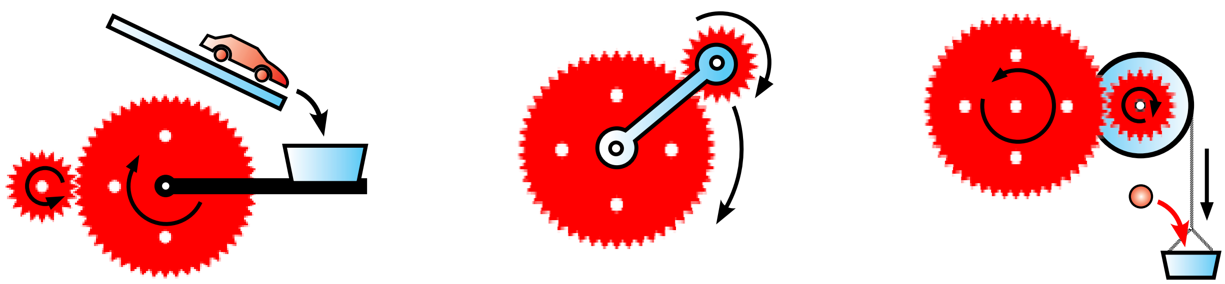
The following examples illustrate torque calculated at the gear axles.



	Axle A (Driving Gear)	Axle B (Driven Gear)
RPM	Less	More
Torque	More	Less

	Axle C (Driving Gear)	Axle D (Driven Gear)
RPM	More	Less
Torque	Less	More

Mechanisms with Gears

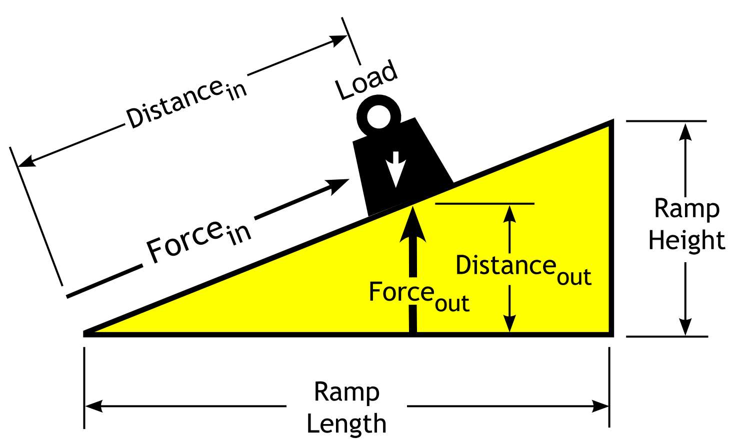


Incline Plane

An incline plane is a sloped surface. By moving an object up an inclined plane rather than directly from one height to another, the amount of effort required is reduced, but the effort must be applied over a greater distance (the object must travel a greater distance).

Ideal Mechanical Advantage

$$\frac{\text{Force}_{out}}{\text{Force}_{in}} = \frac{\text{Ramp Length}}{\text{Ramp Height}} = \frac{\text{Distance}_{in}}{\text{Distance}_{out}}$$

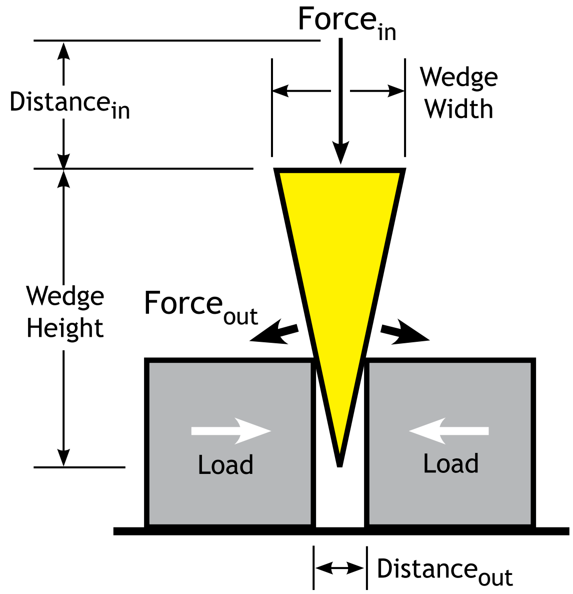


WEDGE

A wedge is a portable inclined plane used either to separate objects, lift an object, or hold an object in place. It converts the input force to force perpendicular to the wedges inclined surfaces.

IDEAL MECHANICAL ADVANTAGE

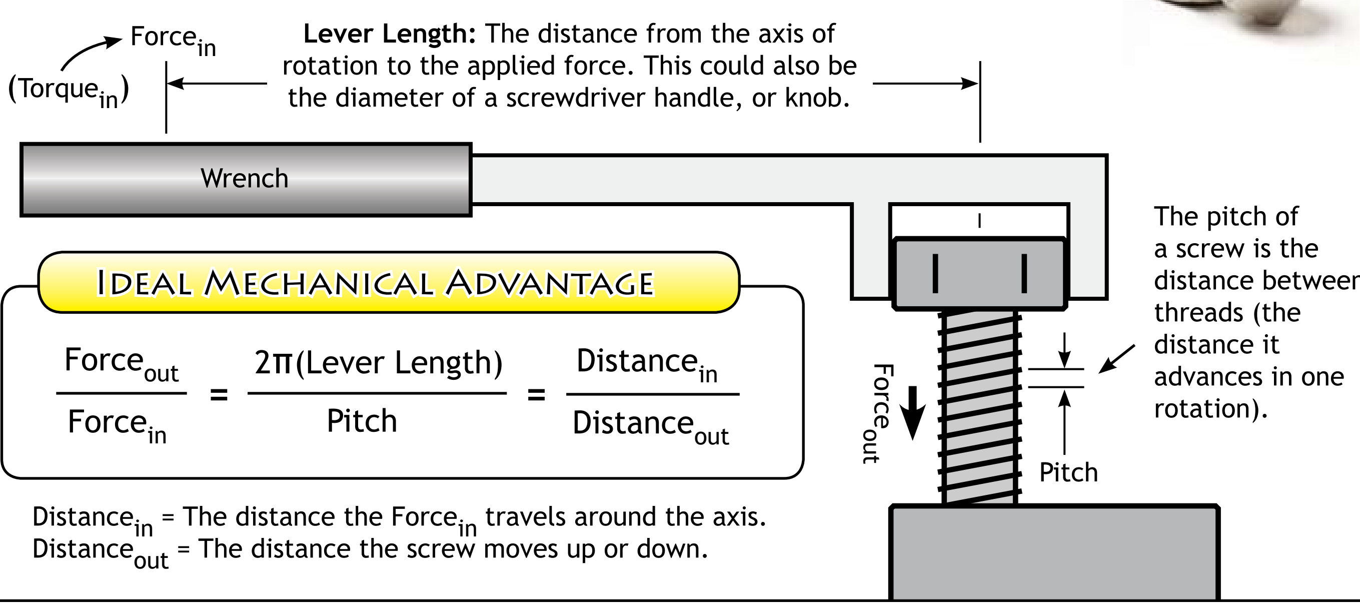
$$\frac{\text{Force}_{out}}{\text{Force}_{in}} = \frac{\text{Wedge Height}}{\text{Wedge Width}} = \frac{\text{Distance}_{in}}{\text{Distance}_{out}}$$



SCREW

A screw is a shaft with a helical groove or thread around its perimeter. Screws are used as a fastener to hold objects together and as a simple machine used to translate torque into linear force.

A screw is really an inclined plane wrapped around a shaft.



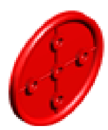
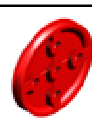
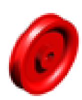
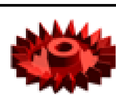
IDEAL MECHANICAL ADVANTAGE

$$\frac{\text{Force}_{out}}{\text{Force}_{in}} = \frac{2\pi(\text{Lever Length})}{\text{Pitch}} = \frac{\text{Distance}_{in}}{\text{Distance}_{out}}$$

Distance$_{in}$ = The distance the Force$_{in}$ travels around the axis.
Distance$_{out}$ = The distance the screw moves up or down.

Investigate & Research: Your Supplies

What supplies will you have to make your contraption?

Part Description:	QTY:	Picture:
Connector Strips		
Birch Dowels .5mm x 620mm		
Wood Strips 5mm x 10mm x 620mm		
Large Glass Marbles		
70mm Pulleys		
50mm Pulleys		
30mm Pulleys		
50 Tooth Gears		
20 Tooth Gears		
Die-Cast Cars		
#12 Screws		

Part Description:	QTY:	Picture:
Paper Cups		
Cardboard Sheets		
Rolls of Thin Wire		
Slide-Stop Material		

Additional Supplies Needed
Part Description
12” x 12” x 1/2” Wooden Bases (Particle Board, MDF, Plywood, etc.) www.TeacherGeek.com Part# TG201
Hot Glue Sticks + Gun
Masking Tape
String
Scrap Paper
Recycled Items (Cardboard Tubes, Yogurt Containers, Corrugated Cardboard, etc.)

Additional Equipment Needed
Part Description
Easy Engineering Tool Set Class Pack
Hot Glue Guns
One Hole Paper Punch
Scissors
Drill (Optional)
Safety Glasses

What “junk” can you find to add to your Crazy Contraption?

Step 3 — The Engineering Design Process
Generate Alternative Solutions

Nothing is more dangerous than an idea, when it is the only one you have.

-Emile Chartier

There is always more than one possible solution to a problem. Your first idea (possible solution) is rarely your best one. This step is about generating multiple, possible, creative solutions to the problem.

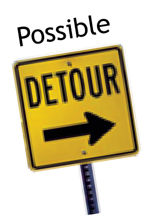
- Be imaginative.
- Challenge basic assumptions.
- Refer to the problem statement and design brief.

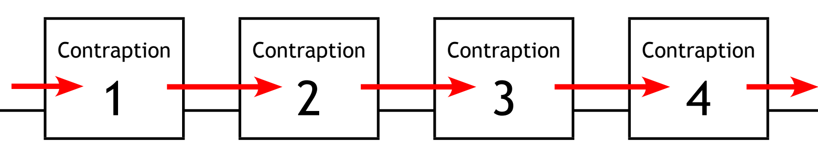
Alternative Solutions

Draw two different Crazy Contraption machines on the "Alternative Design" pages of your portfolio. The designs should be clean, comprehensive and innovative. Additional alternative designs can be stapled to your portfolio.

Will Your Contraption Link?

If your contraption will be linked to other contraptions (Option #2), meet with the connecting contraption groups to complete the "Connecting Contraptions" sheet in your portfolio.





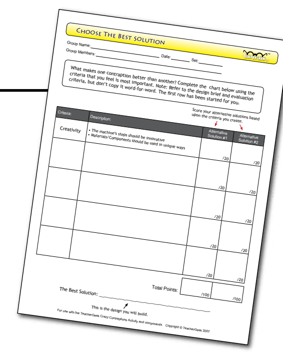
STEP 4

THE ENGINEERING DESIGN PROCESS

CHOOSE THE BEST SOLUTION

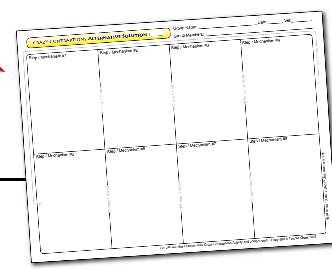
Alternative solutions from step 3 will be analyzed and evaluated to determine which one is the best solution.

CHOOSE THE BEST SOLUTION



Complete the “Choose the Best Solution” page of your portfolio to evaluate your alternative solutions from step 3.

Create a highly detailed drawing of your final solution on the “Final Solution” page. This drawing should be clean, detailed and descriptive enough so that another group could build your contraption without asking you any questions.



STEP 5

THE ENGINEERING DESIGN PROCESS

PROTOTYPING

This is the step you have been looking forward to. It’s time to create a working model of your final design. The first working design models are called prototypes.

Check out the TeacherGeek Easy Engineering Guide to see how to cut, ream and attach Crazy Contraption components.

Building The Frame

The frame will support the contraption mechanisms.

Step #1

You will need a base. The base can be purchased from TeacherGeek, or made using the base template.

Step #2

Insert 4 connector strips, facing the same way, into the base.

Step #3

A. Cut two 150mm (5 7/8”) dowel sections.
B. Cut one connector strip in ½ to get two 150mm (5 7/8”) dowels.
C. Assemble the dowels and connector strips as shown. Dowels should extend 5mm (3/16”) past the connector strips.

Step #4

Attach the assembly from step 3, as shown, into the assembly from step 2.

Your frame is done!!!

BUILD YOUR CONTRAPTION !!!

This is the step you have been looking forward to!!!

Add mechanisms and other components to your frame to build the contraption shown on your final solution sheet.

STEP 6 — THE ENGINEERING DESIGN PROCESS

TEST & EVALUATE

Test your prototype and evaluate how well it satisfies the original design problem.

Create iterations (new versions of your contraption) using the Iterations Sheets in your design portfolio.

Improve/Fix the Design

1. Identify Problems with the Existing Design
2. Investigation and Research ways to fix it
3. Generate Alternative Solutions
4. Choose the Best Solution
5. Tweak/Redesign the Prototyping
6. Test and Evaluate

Continue around the design process until your teacher tells you to stop.

Final Evaluation: All the Crazy Contraptions are tested together.

Complete the Mechanical Advantage Page

Complete the Final Evaluation Page write a concluding paragraph.

Assemble your design portfolio and submit it to your teacher.

Congratulations!!! You're Done.