Hydraulics!

Samples of Possible Common Core and TN Academic Standards to Incorporate:

As you read the activities, keep in mind the specifics skills your students need to practice and master in the different grade levels and use them to guide your approach in how you present the activities and what you have the students do. We encourage you to add additional SPIs and Academic Vocabulary in your plans that are outside the specific ones listed below as there are many which apply and are not listed below.

Kindergarten:

- 7.9.2 Observe, discuss, and compare characteristics of various solids and liquids.
- 7.T/E.3 Use tools to measure materials and construct simple products.
- 7.T/E.1 Explain how simple tools are used to extend the senses, make life easier, and solve everyday problems.

1st Grade:

- 7.9.2 Compare liquids according to their color, ability to flow, solubility in water, and use.
- 7.11.1 Use familiar objects to explore how the movement can be changed.
- 7.T/E.1 Explain how simple tools are used to extend the senses, make life easier, and solve everyday problems.
- RL.1.4. Identify words and phrases in stories or poems that suggest feelings or appeal to the senses.

2nd Grade:

- 7.9.1 Use tools such as hand lenses, measurement devices, and simple arm balances to gather data about the physical properties of different objects.
- 7.T/E.1 Explain how simple tools are used to extend the senses, make life easier, and solve everyday problems.
- W.2.5. With guidance and support from adults and peers, focus on a topic and strengthen writing as needed by revising and editing.

3rd Grade:

- SPI 7.11.1 Identify how the direction of a moving object is changed by an applied force.
- SPI 7.9.1 Describe a substance in terms of its physical properties.
- 7.T/E.1 Explain how different inventions and technologies impact people and other living organisms.

4th Grade:

- 7.11.2 Design an investigation to identify factors that affect the speed and distance traveled by an object in motion.
- SPI 7.11.2 Identify factors that influence the motion of an object.
- 7.9.1 Use appropriate tools to measure and compare the physical properties of various solids and liquids.

5th Grade:

- SPI 7.T/E.2 Recognize the connection between a scientific advance and the development of a new tool or technology.
- 7.T/E.1 Explain how different inventions and technologies impact people and other living organisms.
- 7.10.5 Demonstrate different ways that energy can be transferred from one object to another.

6th Grade:

- 7.10.3 Design a model that demonstrates a specific energy transformation.
- SPI 7.10.3 Recognize that energy can be transformed from one type to another.
- SPI 7.10.4 Explain the Law of Conservation of Energy using data from a variety of energy transformations.

7th Grade:

- 7.11.2 Complete an investigation to determine how machines reduce the amount of force needed to do work.
- 7.11.4 Recognize how a net force impacts an object's motion.
- SPI 7.11.2 Determine the amount of force needed to do work using different simple machines.
- 7.T/E.5 Develop an adaptive design and test its effectiveness.
- 7.T/E.2 Apply the engineering design process to construct a prototype that meets certain specifications.

8th Grade:

- 7.T/E.5 Develop an adaptive design and test its effectiveness.
- 7.T/E.1 Use appropriate tools to test for strength, hardness, and flexibility of materials.
- 7.9.3 Measure or calculate the mass, volume, and temperature of a given substance.
- 7.9.2 Illustrate the particle arrangement and type of motion associated with different states of matter.

High School

- 1.1.24 Understand/Calculate the pressure exerted by a fluid according to Pascal's Principle ($P_{inc} = F1/A1 = F2/A2$).
- 1.1.25 Understand/Calculate how pressure varies with water depth ($P = P0 + \rho gh$).
- 1.1.15 Relate inertia, force, or action-reaction forces to Newton's three laws of motion.
- SPI.1.1.5 Evaluate and describe the phenomena related to Archimedes' Principle, Pascal's Principle, and Bernoulli's Principle.
- 1.Inq.1 Trace the historical development of a scientific principle or theory.
- G-MG.2. Apply concepts of density based on area and volume in modeling situations.

Samples of Possible Academic Vocabulary to Incorporate:

For the Academic Vocabulary we encourage you to use as many of these words as possible, not simply pick one or two. The more words we can introduce in a setting that makes sense to our students, the better.

Kindergarten:

- Beginning
- Ending
- Read
- Drawing
- Tools
- Solid
- Liquid
- Observe
- Poem
- Rhyme
- Position
- Order

1st Grade

- Sequence
- Predict
- Property
- Push
- Pull
- Investigate
- History
- Past
- Present
- Future
- Balance

2nd Grade

- Energy
- Investigate
- Observation
- Similarities/Differences
- Pre-write
- Draft
- Edit
- Dimensions
- Distance

3rd Grade

- Physical change
- Force
- Tools
- Cause
- Effect
- Punctuation
- Synonym
- Antonym
- Verb

4th Grade

- Energy
- Probability
- Convert
- Proofread
- Prediction
- Compare
- Contrast

5th Grade

- Onomatopoeia
- Theme
- Punctuation marks
- States of Matter
- Formula
- Volume

6th Grade

- Cause and Effect
- Criteria
- Design Constraint
- Prototype
- Rhyme
- Rhythm
- Similarity
- Simulation

7th Grade

- Onomatopoeia
- Phenomenon
- Impact
- Property
- Proportional relationships
- Function

8th Grade

- Density
- Inductive & Deductive Reasoning
- Particle Motion
- Density
- Sequence
- Human Impact

High School

- Elements of Design
- Reasoning
- Revision
- Pascal’s principle (fluid, pressure)
- Efficiency
- Thermodynamics
- Compression

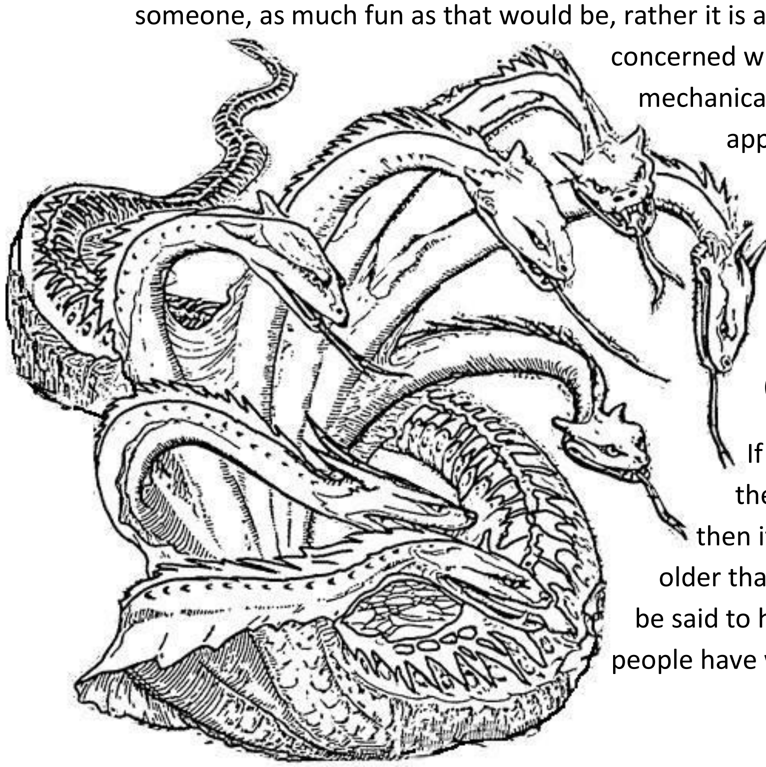
Hydraulics!

Accessing Prior Knowledge: Write key vocabulary words chosen from the lesson on the board (or overhead, etc) and based on the words, ask the students to try and determine the focus of the lesson. This allows you to see if your students have any frame of reference for the topic.

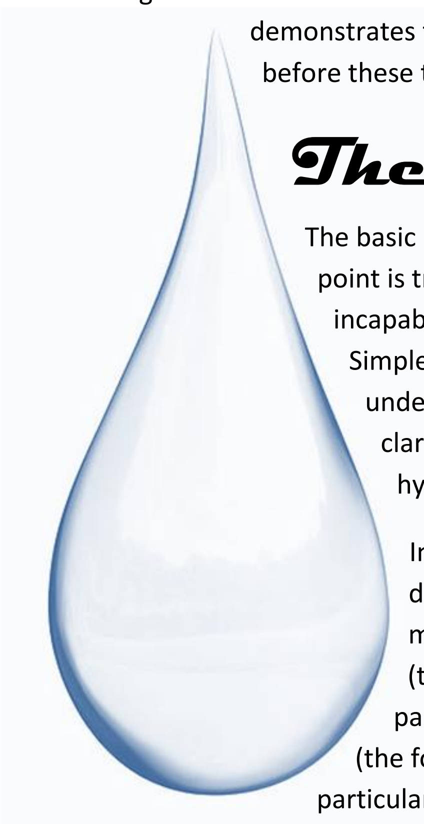
And/Or: Introduce the topic with a science, hydraulics, and/or robot themed books. Pick a book that is relatively simple with pictures that clearly explain what is happening in the book. Ex. *Goodnight, Goodnight, Construction Site*, by Sherri Duskey Rinker, *Oh No!: Or How My Science Project Destroyed the World* by Mac Barnett, or *Boy and Bot* by Ame Dyckman. As you read your chosen book with the class, "think out loud," stopping at appropriate points to articulate your thinking as a model for students, make connections with personal experiences, and other books you might have read with the class. It is important during modeling to continually come back to the text and not allow personal experiences to divert the group from understanding the story.

Hydra Licks?

Okay, hydraulics isn't actually part of a story about a seven headed serpent slobbering all over someone, as much fun as that would be, rather it is a branch of science and engineering concerned with the use of other liquids to perform tasks, mechanical ones. Hydraulics are a very powerful tool for applying a ton of force (no pun intended) where you want, when you want it. The word "hydraulics" comes from the Greek word ὑδραυλικός (hydraulikos) which in turn comes from ὕδραυλος meaning water organ which in turn comes from ὕδωρ (water) and αὐλός (pipe).



If the word hydraulics is understood to mean the use of water for the benefit of mankind, then its practice must be considered to be even older than recorded history itself. No one person can be said to have invented hydraulics, though many many people have worked on it and with it. Throughout time, many civilizations such as the ancient Greeks, the Romans, the SriLankans, and the ancient Chinese mastered the art of using hydraulics. Traces of irrigation canals from prehistoric times still exist in Egypt and Mesopotamia; the Nile is known to have been dammed at Memphis some six thousand years ago to provide the necessary water supply, and the Euphrates River was diverted into the Tigris even earlier for the same purpose. Ancient wells still in existence reach to surprisingly great depths; and underground aqueducts were bored considerable distances, even through bedrock. In what is now Pakistan, houses were provided with ceramic conduits for water supply and drainage some five thousand years ago; and legend tells of vast flood-control projects in China barely a millennium later. All of this clearly demonstrates that men must have begun to deal with the flow of water countless millennia before these times.



The Basic Idea

The basic idea behind any hydraulic system is very simple: Force that is applied at one point is transmitted to another point using an incompressible fluid, which means incapable of losing volume in response to pressure. You can't squish it any smaller. Simple as such matters now seem when taught, they actually took centuries to understand. Particularly noteworthy is the fact that many such principles were first clarified by men like Isaac Newton whose interests extended far beyond hydraulics itself.

Investigations in hydraulics are dependent primarily on the mathematical concepts of density (the mass of an object over a particular volume), force, pressure (the force exerted by an object over a particular area), and mass. In turn, these concepts are governed by the known principles of classical physics, such Newton's laws, the three laws of thermodynamics, conservation of mass, conservation of energy, and laws of motion. The principles of hydraulics on which modern hydraulic-power systems, including hydraulic lifts and brakes, are based is derived largely from the works of French scientist Blaise Pascal (1623-1662) and Swiss physicist Daniel Bernoulli (1700-1782).

This science actually had its origins some two millennia ago in the course of Greek civilization with Aristotle (384-322 B.C.) and Archimedes (287-212 B.C.). Many European scientists also contributed to hydraulics, including da Vinci, Mariotte and Boyle.

Reference Note: The Three Laws of Thermodynamics

1. The first law says that energy can be changed from one form to another, but it cannot be created or destroyed.

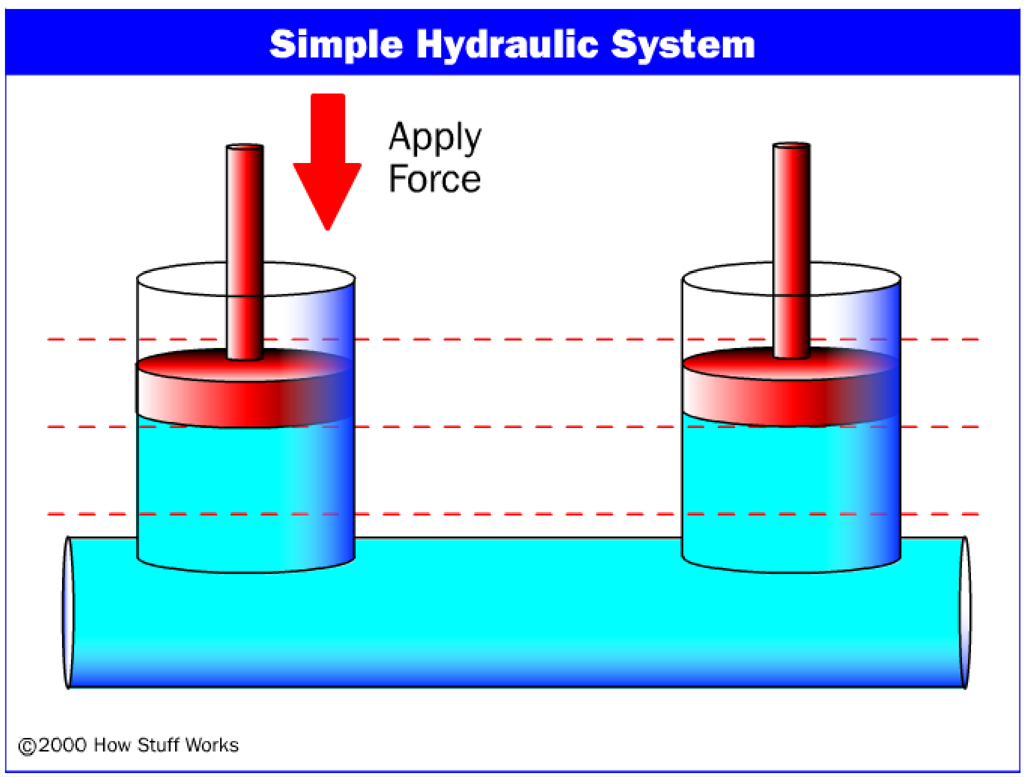
2. The second law of thermodynamics states that the disorder in the universe always increases. We move from order to disorder. As the disorder in the universe increases, the energy is transformed into less usable forms. Because of that, the efficiency of any process will always be less than 100%.

3. The third law of thermodynamics says: It is not possible to reach a temperature of absolute zero. Since temperature is a measure of molecular movement, there can be no temperature lower than absolute zero (about -273 C).

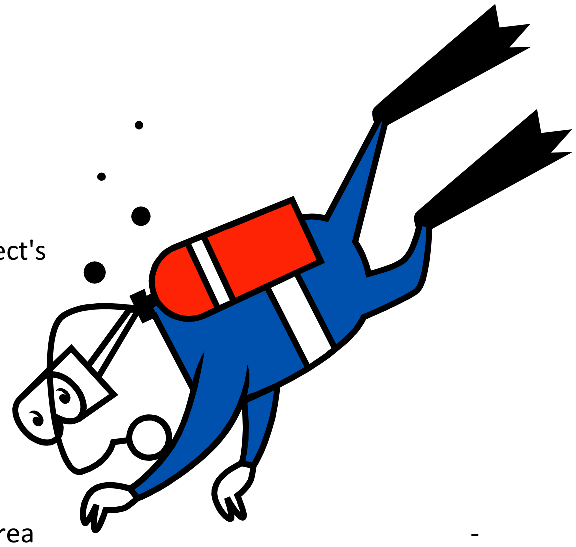
The fluid used in hydraulic machines is almost always an oil of some sort. And what's amazing is the force is almost always multiplied in the process. You give a little push in the beginning and get an even bigger result. The following picture shows the simplest possible hydraulic system, a simple hydraulic system consisting of two pistons and an oil-filled pipe connecting them, pistons are simply "plugs" that can slide freely but snugly inside the tube.

The amazing thing about hydraulic systems is that the pipe connecting the two cylinders can be any length and shape, allowing it to snake through all sorts of things separating the two pistons. The pipe can also fork, so that one master cylinder can drive more than one slave cylinder if desired.

In the drawing, two pistons (red) fit into two glass cylinders filled with oil (light blue) and connected to one another with an oil-filled pipe. If you apply a downward force to one piston (the left one in this drawing), then the force is transmitted to the second piston through the oil in the pipe. Since oil is incompressible, the efficiency is very good -- almost all of the applied force appears at the second piston. The pressure that the left piston exerts against the oil will be exactly equal to the pressure the oil exerts against the right piston. Suppose the tube on the right side is made wider and a piston of a larger area is used; for example, the piston on the right has 50 times the area of the piston on the left. If a 10 kg load is placed on the lift piston, an additional pressure (nearly 1 N/cm2) due to the weight of the load is transmitted throughout the liquid and up against the larger piston. When the area of the piston that receives the pressure is larger than that of the initial piston, the upward force exerted by the second piston is several times stronger than the downward force exerted on the first piston. It's here that the difference between force and pressure is important.



Under Pressure



A force is a push or pull upon an object resulting from the object's interaction with another object.

Pressure: The measure of the force acting perpendicular to a unit area.

Demonstrate pushing with finger compared to pushing with a whole hand against a wall, book, and the hand of a volunteer from the class, with the same force. They can see that pressure is very similar to force, but spread out over an area - therefore the smaller the area it's spread out, the more concentrated the force is, and vice versa.) **Have students think of a water hose. What happens when they want to spray a friend and increase the pressure, what do they do? What happens when you put your finger over the hose and make the space for the water to come out smaller? What happens to the water? Does it come out with more pressure? Why?** The same amount of water is coming through the hose, why does it come through with so much more pressure? You are making the area for the force to act upon smaller, thus increasing the pressure.

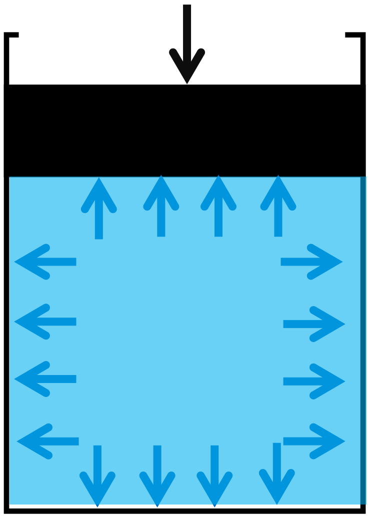
Formula: P = F/A

Even though children might not be ready to understand formulas yet, introducing formulas to even the youngest children, helps them see the relevance of math, and formulas in science.
Explain that the formula pretty much means the same thing as the definition above - Force spread over an area.

If force increases --> pressure increases

If area increases --> pressure decreases

Fluid Pressure: Exerted in all directions equally



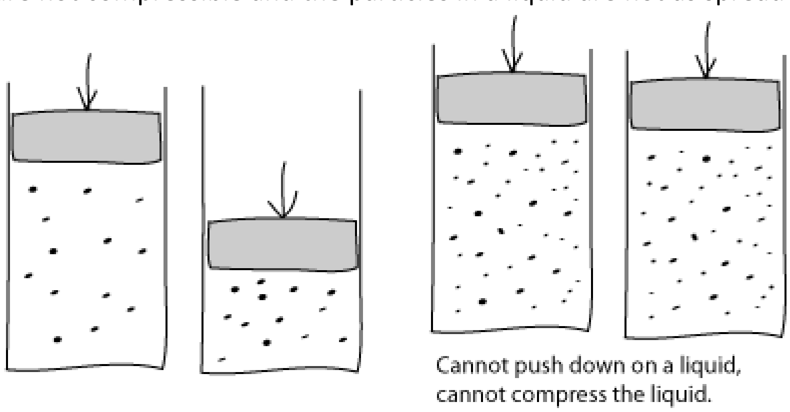
Confined Fluids:

- any fluid in a closed system
- the fluids can move around within the system, but cannot leave or enter the system

Examples:
- blood moving through the body, fluid in your brake lines, or air moving in an air mattress

List as many examples taken from the students themselves as possible.

Gases are very compressible because the particles in a gas are spread out
Liquids are not compressible and the particles in a liquid are not as spread out as in a gas.



Demonstrate this concept for students by taking a syringe, fill it with air, and then cover the open end with your finger. Show that the air can be compressed by pushing down on the plunger. Let the students do this, so that they see it is not some sort of trick. Then fill in the syringe with water. Again covering the end with your finger, show that now you cannot compress the water with all your might. Try very very hard to make sure they see your effort. **Get students to replicate this**. **Challenge students to a Pascal-syringe “thumb war” using connected syringes filled with water.**

Examples of questions for discussion:

- If you fill in the syringe with 20mL of air, to what volume can you compress it?

- If you fill in the syringe with 20mL of water, to what volume can you compress it?
- What is the difference between compressing air and water?
- Attach two syringes with some tubing with air in the confined system. What happens when you press on the plunger?
- Attach two syringes with some tubing with water in the confined system. What happens when you press on the plunger?
- Attach three syringes (two of the same size, and one larger) with some tubing and a T valve. What happens when you press on one plunger?
- Attach three syringes with some tubing and a one way valve. What happens when you press on one plunger?

That Rascal, Pascal!

As mentioned earlier, when the area of the piston that receives the pressure is larger than that of the initial piston additional pressure is exerted against every square centimeter of the larger piston. Since there is 50 times the area, 50 times as much force is exerted on the larger piston. Thus, the larger piston will support a 500 kg load - fifty times the load on the smaller piston! *Forces* can be easily multiplied using such a device.

This is what Pascal saw, when, according to history, in 1646, Blaise Pascal, a French mathematician, performed the famous experiment of inserting a long perpendicular tube of small caliber into the top of a tight wooden barrel that was closed and already filled with water. **What do students think he was going to do with the barrel?** He continued to pour water into the tube so that it filled up. **What do they think happened when he filled up the tube? Encourage them to think of your earlier discussion about hydraulic pressure.** When the water level reached the top of the tube, the barrel exploded from the intense water pressure. **Why?** Pascal saw that the pressure at the bottom of a column of liquid was proportionate to the height of the column, and not to its bulk and that the force was multiplied. To put it in more understandable terms, the barrel is a crude form of a hydraulic device, if that makes it easier to visualize. Although you are exerting a relatively small force on the small cylinder, that force becomes a pressure in the liquid. It may help to draw a diagram on the board. **Have students direct as it is drawn, where the pressure arrows should point and label where the force is multiplied.** If you transfer that pressure to another connected cylinder of larger diameter you are applying the same pressure over a larger area, effectively multiplying the force. This led to his later inventions including the hydraulic press (using hydraulic pressure to multiply force) and the syringe. He had proven that hydrostatic pressure does not depend on the weight of the fluid but on the elevation difference.

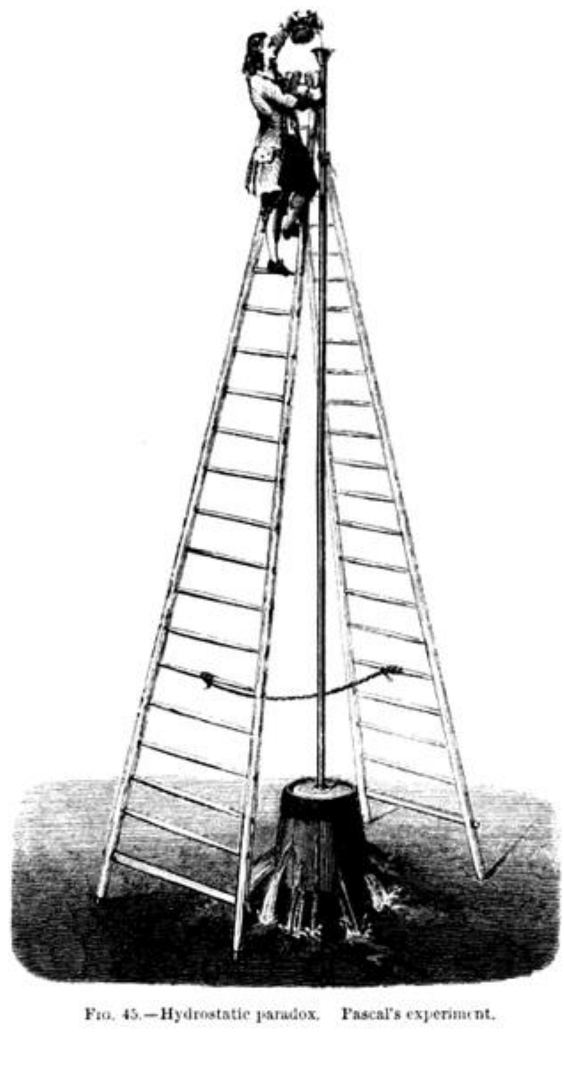


Fig. 45.—Hydrostatic paradox. Pascal's experiment.

Bottomless Bottle- A Demo of Pascal's Law

While pursuing medical studies and in particular studying the flow of blood through the body, Pascal declared in 1652 that pressure applied to any confined, incompressible liquid will be applied equally to the liquid and the container holding the liquid in all directions, with no loss**.** This statement is known as Pascal's law (or Pascal's principle) and can be succinctly written that $\text{pressure}_{in} = \text{pressure}_{out}$. Use this old parlor trick to dramatically demonstrate Pascal's law of equal pressure and the incompressibility of fluids. **Practice this demonstration before you do this with students!**

Materials:

- Glass bottles with screw-on caps
- Rubber Mallet (**DO NOT use your hand, there is risk of injury**)
- Work Gloves *Protective gloves are highly recommended when performing this demonstration.*
- Water
- Safety Goggles *Protective eyewear is highly recommended when performing this demonstration.*
- Sink/Outdoors

1. Fill a glass bottle with water. **Ask students what they think will happen, is the pressure equal right now? Guide them to think of Pascal's Law. What will happen if we add pressure in to the bottle? Should we leave the lid on or off?**

2. Put on Work Gloves/Safety Gloves and safety goggles/protective eyewear.

3. Firmly grip the neck of the bottle, give the **top** (only the top) of the bottle a whack **with a rubber mallet** and-Pop! The bottom of the bottle drops out. (*You may have to give several whacks, it doesn't always work first time every time with certain bottles, a science project for students perhaps to figure out why? Which type of bottle works best? Are some seals stronger than force?*)

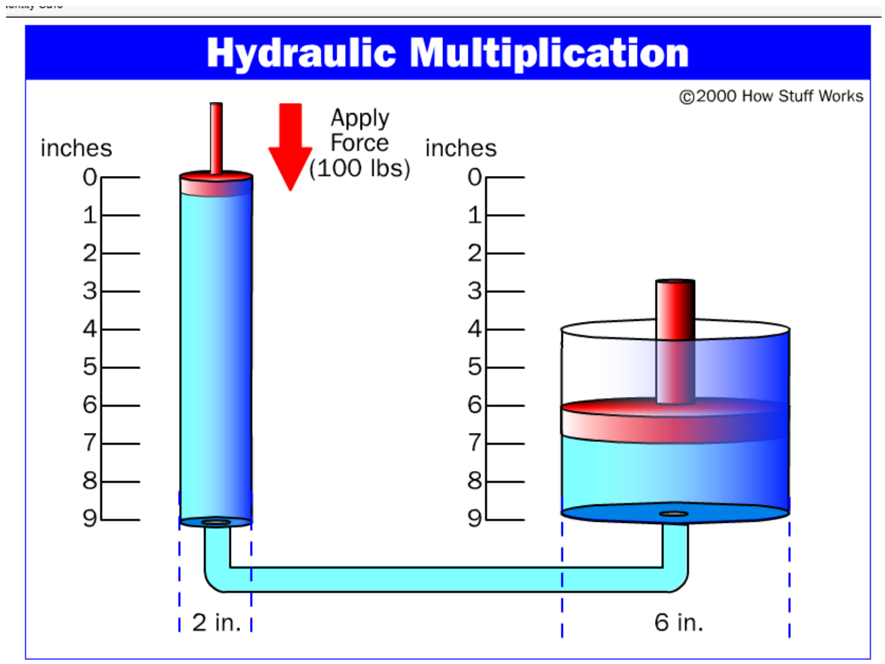
What happened? What caused the bottom to drop out of the bottle? Did we really hit it that hard? How did the force move from the top of the bottle to the bottom? The small force applied to the water in the narrow neck of the bottle becomes a much larger force on the bottle's wider bottom- Pascal's law in action! The force is large enough to break the glass at the base of the bottle. **What if you leave the lid off, does it still work?**

The reason this demonstration works is because the sudden increase in pressure is transferred throughout the bottle, by Pascal's Principle. An even distribution of force presses on the bottom of the bottle. The seam just above the bottom just happens to be the weakest "joint" in the bottle, so that's where the bottle gives way. Note that because the bottle cap is much smaller than the bottom of the bottle, the liquid inside exerted more force on the bottom than the hand or rubber mallet exerted on the fluid. Furthermore, the bottom need be moved outward only on a molecular scale---the width of a few atoms---to break the seam around the bottom, while the hand hits the cap inward over a far greater distance. Therefore, the bottom drops out by being subjected to a greater force, albeit over a shorter distance.

Recall that energy, as work, is force times the distance over which the force is applied. Therefore, energy is conserved in this demonstration because the force on the bottle bottom moves the bottom such a small distance. Like a mechanic's car lift, the bottle demonstration is a mix of both Pascal's Principle and the concept of leverage in magnifying force while still conserving energy.

Multiplying Forces

As we've noted, the neat thing about hydraulic systems is that it is very easy to add force multiplication (or division) to the system. Trading force for distance is very common in mechanical systems. In a hydraulic system, all you do is change the size of one piston and cylinder relative to the other.



In our picture, the larger area is nine times greater than the smaller area. In order to move the larger piston one inch, the smaller piston has to move nine inches.

Now, students get to become hydromechanics and try it for themselves.

Materials:

- Water
- Aquarium Tubing
- 2.5 cm^3 syringes
- 10 cm^3 syringes
- Books, bricks, or other heavy objects
- Option: sealant or waterproof tape for security

A simple hydraulic multiplication activity can be conducted using a 2.5 cm^3 and a 10 cm^3 syringe connected by a 1m long piece of aquarium tubing filled with water. Have students fill one syringe with water. Attach 30.5 cm long tubing to syringe. Squeeze syringe until water starts to drip from tubing. Put tubing in water and fill syringe and tubing completely with water. Attach empty (plunger all the way in) syringe to other end of tubing. *Any air bubbles in the tubing or syringe will restrict the desired* *motion.* As one plunger is pushed down the other is pushed out. Force is transmitted through the water from one syringe to the other. ***Have students follow precisely a multistep procedure to put together their hydraulic system and when carrying out their own experiments, taking measurements, or performing technical tasks.*** Note: This experiment may be best outdoors as water-filled tubes can leak.

Once the set-up is put together, how far does the plunger of the big syringe move out when students push in the small syringe 4 cms?

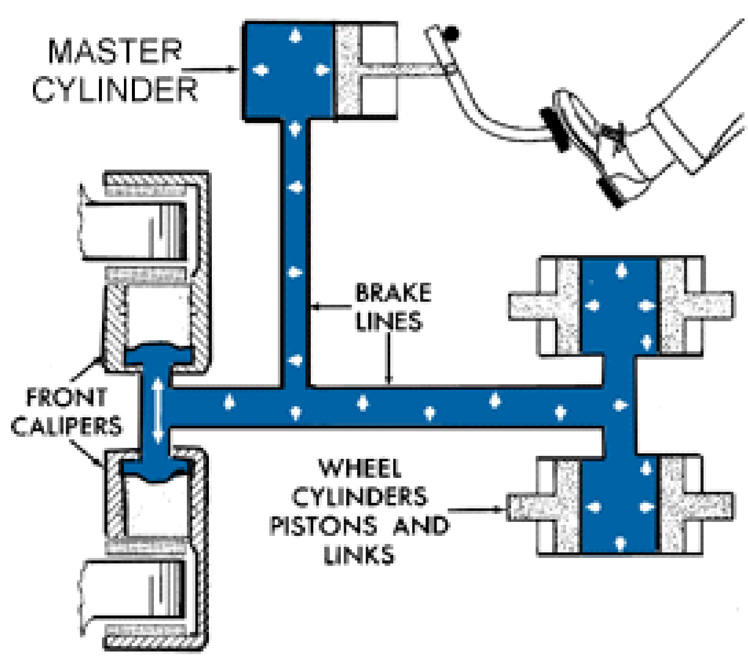
Ask your students to place their thumb over one of the plungers and try to stop it from moving outwards while their partner presses down on the other. **Can they feel any force?** Which syringe, the 2.5 cm3 or 10 cm3, will they use to push their partner's thumb upwards?

Now, have students set up their own experiment, ex. they may try to lift a heavy object like a book, or a brick, or try to use more than two syringes. ***When lifting objects is it best to put the small syringe under the heavy object, as shown in the picture, or is it best to put the bigger syringe under the heavy object?***

For older students: To have students determine the multiplication factor, draw a simple illustration on the board of the diagram above and have students start by looking at the size of the pistons. Assume that the piston on the left is 2 inches in diameter (1-inch radius), while the piston on the right is 6 inches in diameter (3-inch radius). The area of the two pistons is Pi * r2. The area of the left piston is therefore 3.14, while the area of the piston on the right is 28.26.

Now we know that the piston on the right of the diagram is 9 times larger than the piston on the left. What that means is that any force applied to the left-hand piston will appear 9 times greater on the right-hand piston. So if you apply a 100-pound downward force to the left piston, a 900-pound upward force will appear on the right. **What's the catch? What do you have to do in order to raise the piston on the right one inch?** The only catch is that you will have to depress the left piston 9 inches to raise the right piston 1 inch.

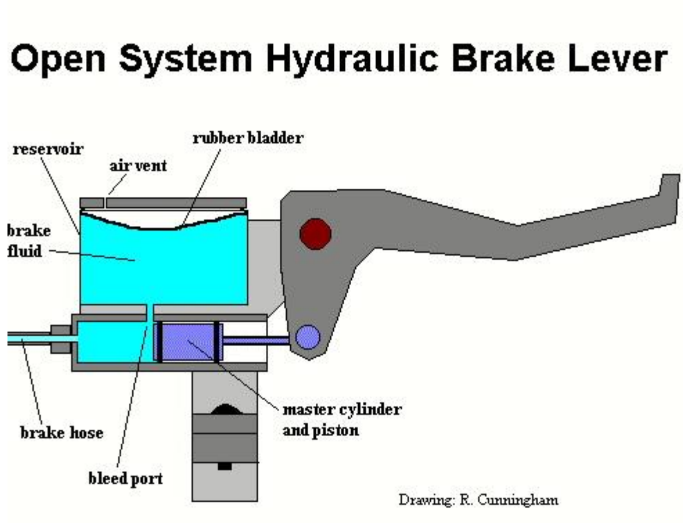
The brakes in your car are a good example of a basic piston-driven hydraulic system. When you press down on the brake pedal in your car, it is pushing on the piston in the brake's master cylinder. Four slave pistons, one at each wheel, actuate to press the brake pads against the brake rotor to stop the car. (Actually, in almost all cars on the road today two master cylinders are driving two slave cylinders each. That way if one of the master cylinders has a problem or springs a leak, you can still stop the car.)



Now, for example, let's say the piston

behind the brake pedal is .01 square inches and you push down on the brake pedal with 100 pounds of force. You end up with (100 divided by .01) 10,000 pounds per square inch of pressure being transmitted to the brake cylinders. If each brake piston has an area of two square inches, there is (10,000 times 2) 20,000 pounds of force pushing the brake pads against the rotor (at each corner of the car) to stop the car. In this way, your 100 pounds of force on the pedal is translated into 80,000 pounds of stopping power.

For those students who can't drive, have them think of their bikes, if they have ever ridden one. Many bicycles have hydraulic brakes. **When you squeeze the brakes on the handles of a bike, what happens?** The brake lever uses hydraulic fluid to transmit the force from your hand to the brake shoes. The handle presses a small piston that applies pressure to the fluid in the line. At the wheels, a larger piston squeezes the pads onto the disc, squeezing the brake pads against the outside of the wheel. Since this piston is larger, the force is multiplied at the wheels, meaning it presses harder on the wheels than you pressed on the handles. **Why do students think brakes in cars and bikes get "soft"? Did any leaks happen in the hydraulic systems they created earlier? What might leaks do to brakes? What could friction do to brakes? Have they ever seen brake pads get thin? If the brake pads are thin, what does the hydraulic system have to do/what do you have to do in order to stop the same amount? Press harder!**



In most other hydraulic systems, hydraulic cylinders and pistons are connected through valves to a pump supplying high-pressure oil. Big hydraulic machines usually have:

Large appetites for hydraulic oil (100 gallons is not uncommon if there are six or eight large hydraulic cylinders used to operate the machine.) Large external reservoirs are sometimes used to hold the difference in the volume of oil displaced by the two sides of any cylinder.

Braking Down

Now, using materials they experimented with earlier, and other easily available supplies, have students set up their own experiment to model a bike or other braking system.

Materials:

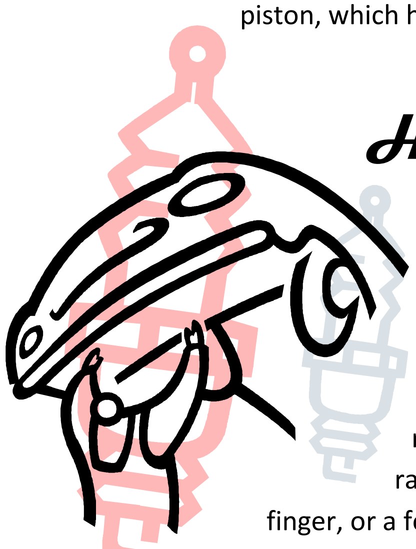
- Disposable syringes

- Nails
- Hammers
- Aquarium tubing
- Cheap toy wheels
- Pencil erasers
- Two wooden blocks

1. First, have students fix the wheel on to the wooden block with a nail in such a manner that it can rotate freely.
   As they did earlier, have the students fill the syringes with water and connect them both with the rubber tube.
2. Then, have them, at the end of a piston of one of the syringes fix the rubber eraser.
3. Using a tape students will fix this syringe to the second wooden blocks and then arrange their materials.
4. Have them rotate the wheel. Then they press the piston of the other free syringe and they will see the piston of the fixed syringe coming out causing the eraser to stop the rotating wheel.

Can students come up with any other experiments or ideas to test or areas to possibly apply their system? How could they modify it? Can they stop multiple wheels at the same time with one master cylinder or two and a pair of t joints? How could they work it from a longer distance? How long can the hose be and still retain effectiveness?

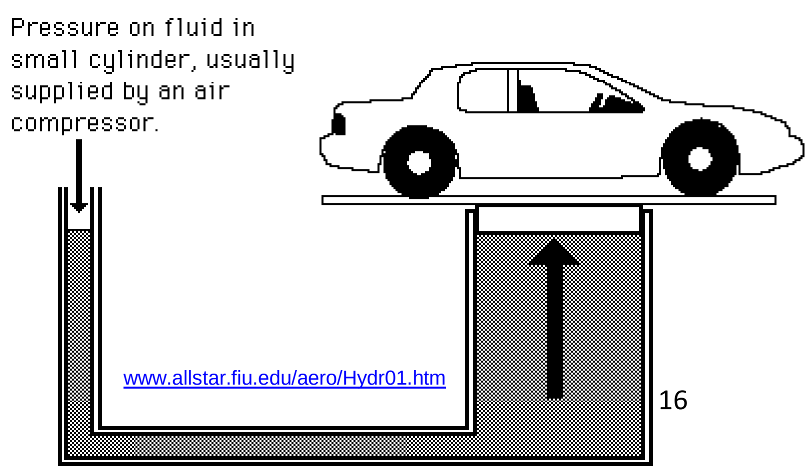
Note: Air in the System
It is important that a hydraulic system contains no air bubbles. You may have heard about the need to "bleed the air out of the brake lines" of your car. If there is an air bubble in the system, then the force applied to the first piston gets used compressing the air in the bubble rather than moving the second piston, which has a big effect on the efficiency of the system, as your students may notice.



Hydraulic Lift

Can you lift a car? No? You say you are not strong enough? True, our bodies are not built to lift heavy loads like cars. Fortunately, our brains are smart enough to harness the power of fluids, like water and oil, to create hydraulic lifts. By pushing a button on a hydraulic lift, a mechanic can easily raise a car with one finger, or a few pumps.

Lifts can also be used to raise lots of other heavy loads - even such massive things as steel girders to construct a

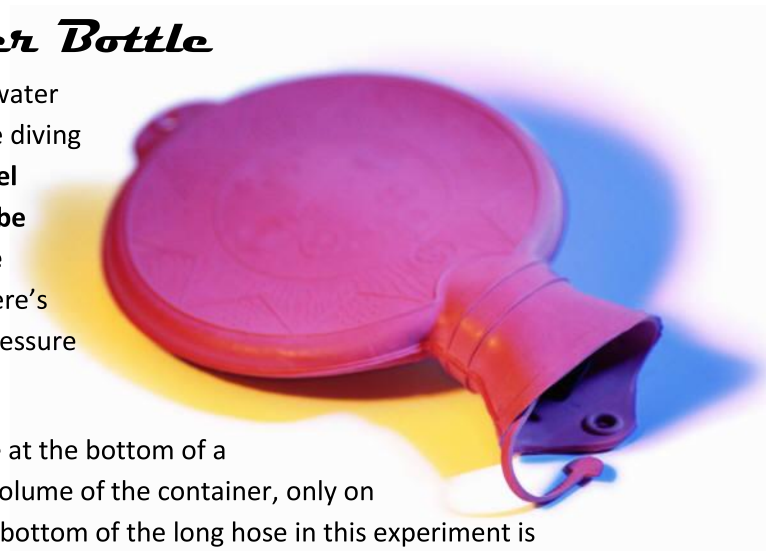


www.allstar.fiu.edu/aero/Hydr01.htm

skyscraper! *For a visual demonstration, in the following video, Discovery Channel's "Massive Engines," host Chris Barrie demonstrates the concept of the hydraulic pump. The hydraulic pump was invented by Joseph Bramah during the Industrial Revolution.* http://videos.howstuffworks.com/discovery/34870-massive-engines-hydraulic-pumps-video.htm

In this mechanical engineering project, students will get a firsthand look at the power of a hydraulic system and experience a very simple hydraulic system at work:

Hydraulic Hot Water Bottle



The pressure at the bottom of a column of water depends on the depth of the water. Imagine diving into a swimming pool. **What do students feel when they dive deeper? Have them describe what happens and draw diagrams and take notes on the board**. As you dive deeper, there's more water pushing down on you, so the pressure on you is greater.

Pressure is force per unit area. The pressure at the bottom of a container doesn't depend on the shape or volume of the container, only on the depth of the water. The pressure at the bottom of the long hose in this experiment is large, because of the depth of the water above it.

The hot water bottle has a much bigger area than the opening of the hose. Since pressure is force per unit area, the same pressure on a much bigger area creates a big force that can lift the person standing on the hot water bottle. As we know, a system like this, where a fluid is used to transfer force, is called a hydraulic system.

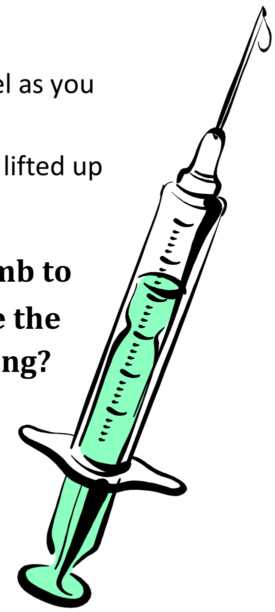
Materials:

- Rubber hot water bottle
- Funnel
- Hose/tubing that is included with water bottle **(DO NOT try this with aquarium tubing unless you have waterproof tape and a really tight seal, it will leak! And the demonstration will not work.)**
- Syringes
- Optional: Cardboard or Thin Plywood Squares

Preparation:

1. Attach the hose **securely** to the water bottle, you will want to make sure it is a tight seal. For this, the hose that comes with the water bottle works best.
2. Tape the funnel to the other end of the hose so that it is securely fastened.
3. Place the empty hot water bottle flat on the floor.

4. Choose a volunteer to stand on the hot water bottle, you may want to put a flat cardboard or plywood board on top, to help with balance and for the student to have enough area to stand on, but it is not required.
5. Attach the end of the hose to the water bottle (with tape if necessary to prevent water escaping).
6. Pour the water into the funnel while it is at waist height.
7. Once a small amount of water has entered the hot water bottle, lift the funnel as you continue pouring (standing on a chair if necessary).
8. The class will see the volunteer struggle to maintain their balance as they are lifted up (this may take a few minutes as the water takes a while to fill the apparatus).



Now, try this. Can you easily lift a student with the press of your thumb to demonstrate a hydraulic jack if you make it a closed fluid system (like the small version created earlier) with a syringe at the top end of the tubing?

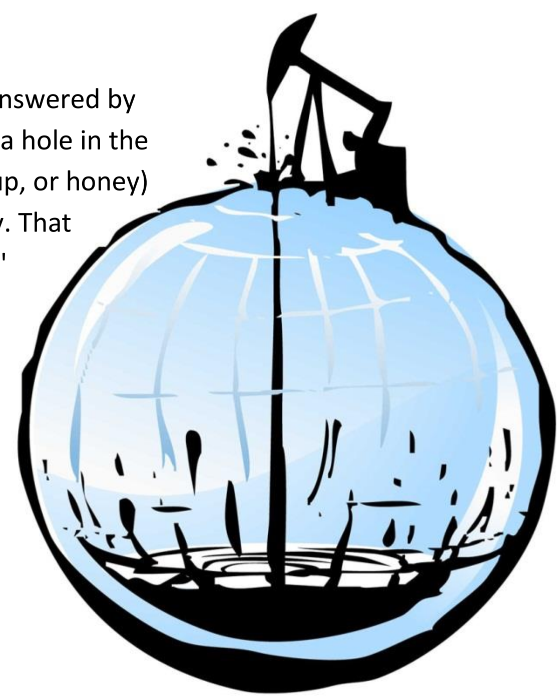
Discussion Questions:

- Which is heavier, the volunteer or a liter of water?
- What would happen if the funnel or syringe was kept at a low level e.g. knee height?
- Could you lift an elephant the same way?
- How could you use this principle to do physical work, like to move things?

Like Oil and Water

Why do most hydraulic systems use oil instead of water? The short answer: Cost effectiveness.

The long answer: Using water as a hydraulic fluid is actually entirely possible for many applications, but produces several additional challenges which will dramatically and likely prohibitively raise the price of the machine. For most applications, the higher costs will represent an unmarketable product because no one wants to pay that much when it would be cheaper to buy an oil based machine. So what's the big deal? Well, the issues include:



- Viscosity: What is viscosity? This question is often best answered by example. **Show students**. Imagine a Styrofoam cup with a hole in the bottom. If I then pour oil (or another liquid like corn syrup, or honey) into the cup you will find that the cup drains fairly slowly. That is because oil viscosity is large compared to other liquids' viscosities. **If you fill the same cup with water, for example, what will happen?** The cup will drain much more quickly.
  Viscosity is a measure of a fluid's resistance to flow. It describes the internal friction of a moving fluid. A fluid

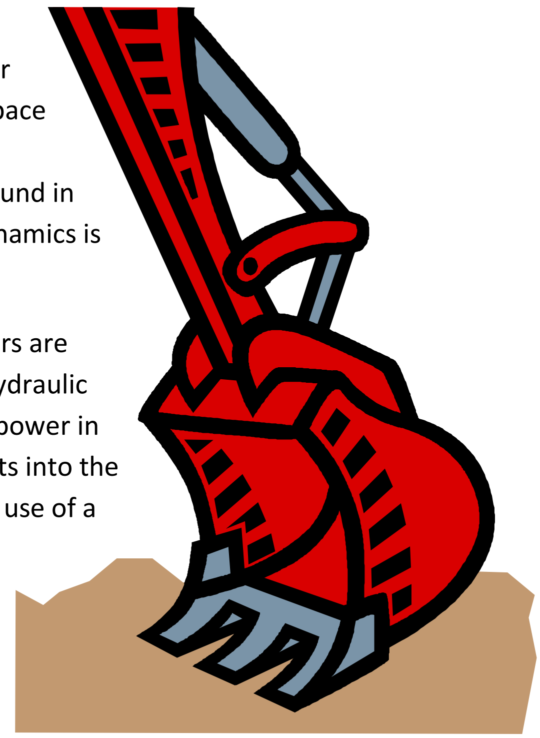
with large viscosity resists motion because its molecular makeup gives it a lot of internal friction. A fluid with low viscosity flows easily because its molecular makeup results in very little friction when it is in motion.

Water has a much lower viscosity than hydraulic oil. This results in at least 3 other issues. First, the piston and cylinder materials (usually steel) will erode (rust) much quicker due to the resulting higher velocity and more turbulent flow. Second, the use of special valves will be required to prevent the mechanical shock caused by abrupt fluid flow stoppage inherent to water. Third, the lower viscosity (the fact it's thinner than oil) also means it will be more difficult to prevent leaks, requiring more stringently machined parts with much finer tolerances.

- Bacteria: A closed water system can provide a breeding ground for all kin ds of microorganisms. This can result in clogged lines, filters and a potentially unsafe/unhealthy condition in the event of a leak. These kinds of bacteria won't grow in oil.
- Corrosion: Oxygen in the water as well as sulfurous by-products from bacteria can potentially corrode component materials. Water can cause steel components to rust. Oil is much less corrosive.
- Temperature Range: Water freezes at 32 degrees Fahrenheit. If freezing occurs, and due to the non-compressible nature of ice, it will almost certainly damage or destroy hydraulic parts. Anti-freeze agents will need to be utilized at the cost of the inherent environmental and toxicity concerns of such substances.
- Lubricity: Water's comparatively low lubricity will lead to increased contact friction and resulting wear of components. Hydraulic oil is an excellent lubricant

All of these issues can be addressed and overcome, with the disadvantage of dramatically higher cost vs. hydraulic oil.

Hydraulic Machines



The history of hydraulic systems is found in dam design and engineering. It is found in the field of automobile, aviation, bicycles, railways, and your local gym's workout equipment. It is found in military applications and space exploration and in other disciplines where fluid circuitry is used such as turbines, pumps, and hydropower. The history of hydraulic systems is found in the current development of the computer where computational fluid dynamics is a buzz term.

This history is found wherever hydraulic machinery and hydraulic cylinders are located. One of the best places to get up close and personal with large hydraulic machines is at a construction site. Hydraulic machines make use of fluid power in order to do mechanical work. The concept is that high-pressure liquid gets into the motors and cylinders of the machine. To do this, the entire set up makes use of a series of control valves, hoses and tubes to route the hydraulic fluid.

From backyard log splitters to the huge machines you see on construction sites, hydraulic equipment is amazing in its strength -and agility! On any construction site you see hydraulically operated machinery in the form of bulldozers, backhoes, shovels, loaders, fork lifts and cranes.

Hydraulics operate the control surfaces on any large airplane. You see hydraulics at car service centers lifting the cars so that mechanics can work underneath them, and many elevators are hydraulically operated using the same technique. Even the brakes in your car use hydraulics!

The thing that is most amazing about these machines is their sheer size. Now, we don't exactly have the space to build large construction site sized machines, so we're going to build some miniatures that use a simple hydraulic system and some awesome hydraulic power! Project-based learning, or PBL, allows students to control the direction and pace of their learning, which in itself can transform classwork into a fun and exploratory process. Activities that promote investigation, creative critical thinking, and hands-on subject matter are also central to project-based learning.

In the following activities, students will learn about the basic principles that hydraulic systems use to do their work, and then we'll engineer different pieces of

hydraulic machinery. They will be amazed at the power and versatility available with hydraulics.
The following projects are thanks to Lance Akiyama and The Workshop for Young Engineers.

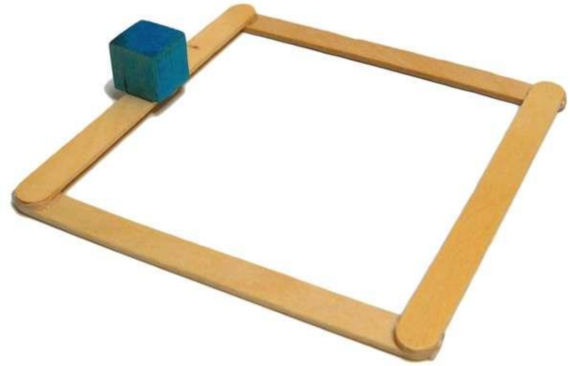
Learning Objectives

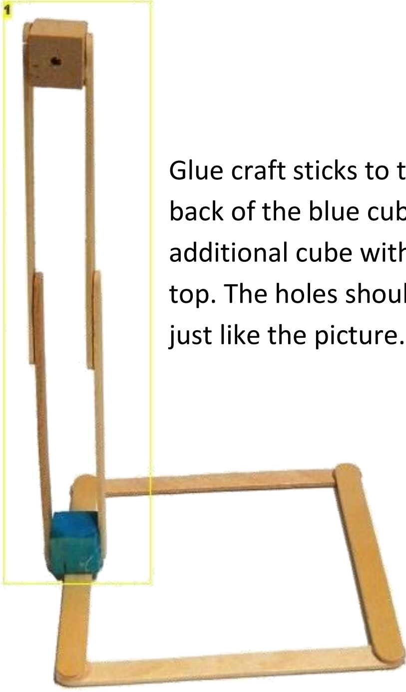
- By creating a simple hydraulic system, students will comprehend the basic mechanics behind hydraulics (transferring kinetic energy from one piston to another by pushing water through the tubing).
- Applying these hydraulic systems to simple machines will allow students to experientially understand how hydraulics can be used to power machinery.
- Building the simple machines will give students an understanding of how hinges and levers work.
- Finally, students will refine their critical thinking and motor skills as they build, test, and redesign their easy hydraulic machines.

Simplest machine

The video at http://www.instructables.com/id/Easy-Hydraulic-Machines/ gives you an overview of the simplest hydraulic machine - the photos tell you how to build it!
Materials

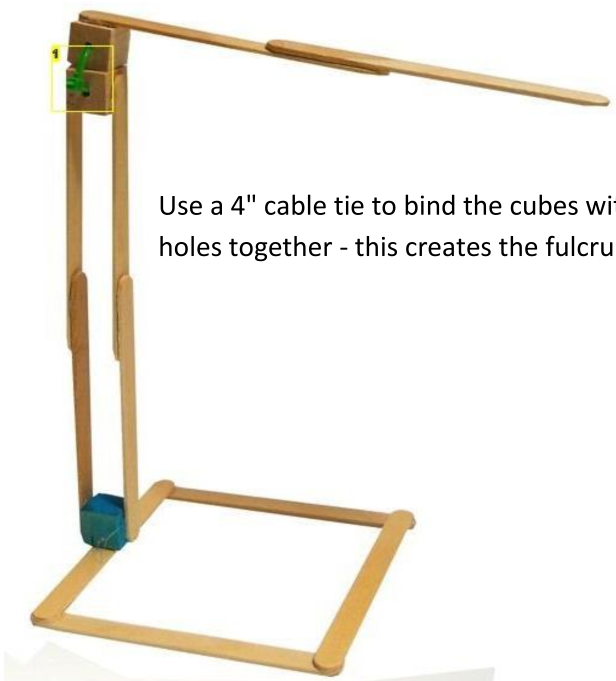
- These are the essential materials, but you could of course add to this list.
- Craft sticks, craft cubes, cubes with holes, skewers (less than 1/8" diameter),
- 10ml plastic syringes (bulk),
- vinyl tubing,
- cable ties,
- tape
- craft/hot glue



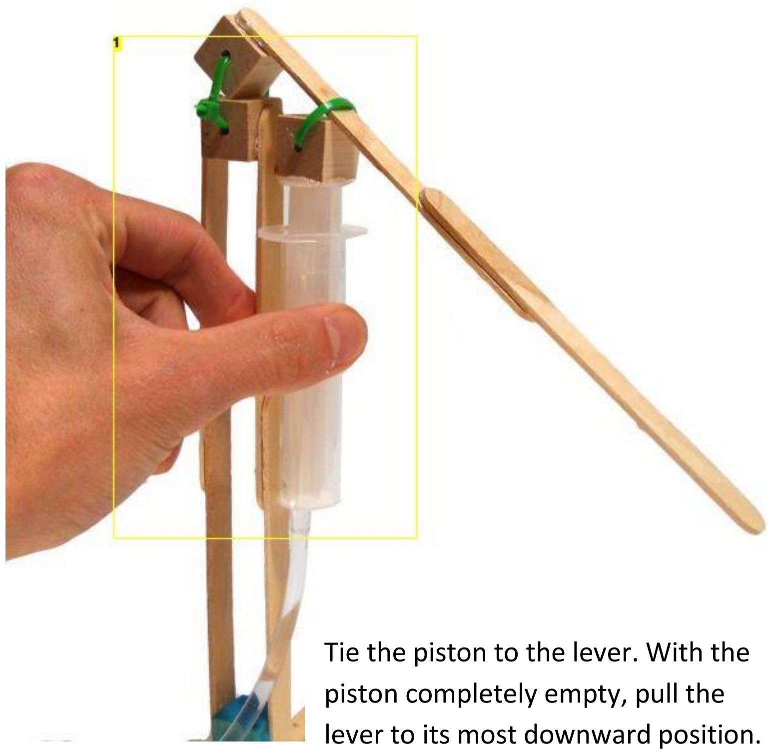


Glue craft sticks to the front and back of the blue cube with an additional cube with holes at the top. The holes should be exposed just like the picture.

The lever can be this simple, but can also be much longer/stronger/more interesting



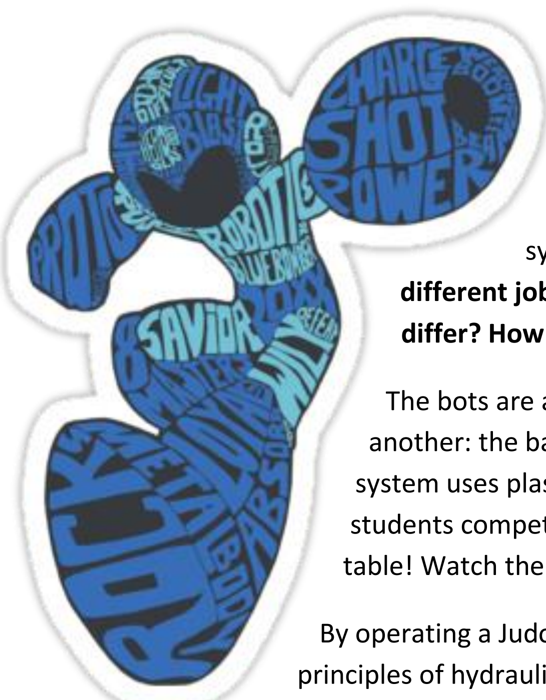
Use a 4" cable tie to bind the cubes with holes together - this creates the fulcrum.



Tie the piston to the lever. With the piston completely empty, pull the lever to its most downward position. Tape the piston in place as it's shown in the very first picture.

Let the students get creative!

Now that students have the basics,
it's time for battle!



Judo Bots!

They're called JudoBots because of the way they seem to throw and grapple with each other during combat. The project involves constructing a robot that uses a simple hydraulic system to power a lifting arm and a pivot. **What are some of the different jobs a robot might do? Are all robots the same? How do they differ? How do robots move? Do all robots move the same?**

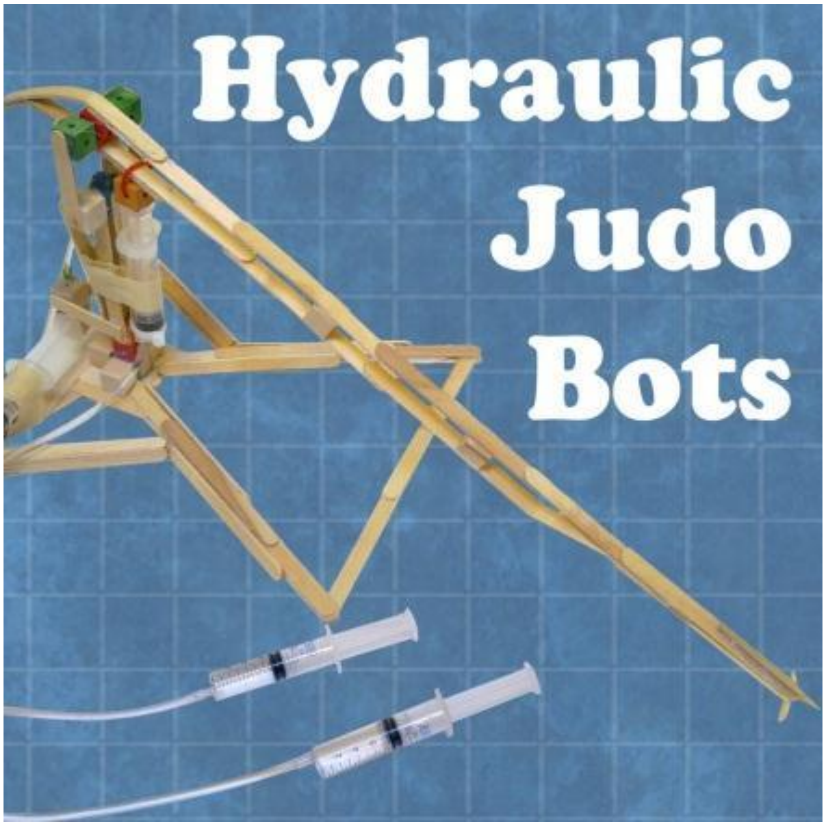
The bots are assembled from four components built separate from one another: the base, the stand, the arm, and the hydraulic system. The hydraulic system uses plastic syringes as pistons and water as the hydraulic fluid. Then students compete, two robots facing off and trying to throw each other off of a table! Watch the video... http://www.instructables.com/id/Hydraulic-JudoBots/

By operating a JudoBot, students will experientially comprehend the basic principles of hydraulics. Building and testing Judobots offers students the opportunity to evaluate materials based upon density, rigidity, and mass. Using the JudoBots in battle gives students hands-on knowledge of how to utilize hydraulics to effectively apply leverage to manipulate a mass. When the project is finished, students will walk away with a new appreciation of applied engineering (and an awesome new toy!) **After building them, testing them, and compteting with them, discuss: What methods made the robots move the fastest? What things made the robots move with the most accuracy or the most precision? If students could ask for 2 additional parts, what would they be, and why?**

Materials, tools, and design criteria:

- Craft sticks

- Craft cubes [small wood blocks]
- Cubes with 5/32" holes [1/2" Square Beads, rounded edges w/ 5/32" hole]
- Robust wooden skewers 1/8" diameter
- Decorative woodcraft (optional)
- 10ml plastic syringes
- Vinyl tubing
- Adhesive bumpers
- 4" cable ties
- Masking tape
- Hot glue guns or very strong craft glue
- Glue sticks
- Multicutter or clippers (recommended)
- Food dye (optional)



JudoBot Criteria

1. The base of each JudoBot must fit within a 10-inch square. This is to prevent students from building sprawling robots that cannot be flipped.
2. Material limitation: craft sticks (50), craft cubes (10), cubes with holes (10), syringes (4), adhesive bumpers (10), decorative woodcraft/extra woodcraft (5), everything else within reason.

Material limitations are in place to promote resourcefulness and to reduce cost. Also, clever students can no longer pile hundreds of sticks onto their bot in order to make it too heavy to move. Although the cubes depicted have holes drilled on all sides, this is not necessary.

You may choose to use other materials. This is what I use because I need to streamline my materials to fit with the other projects in my program, as well as keep the cost per project low.

Use masking tape to secure the piston that actuates the pivot, not cable ties. Students requesting for help tends to bottleneck at this step, so using tape is much easier to attach and readjust (and it's just as effective).

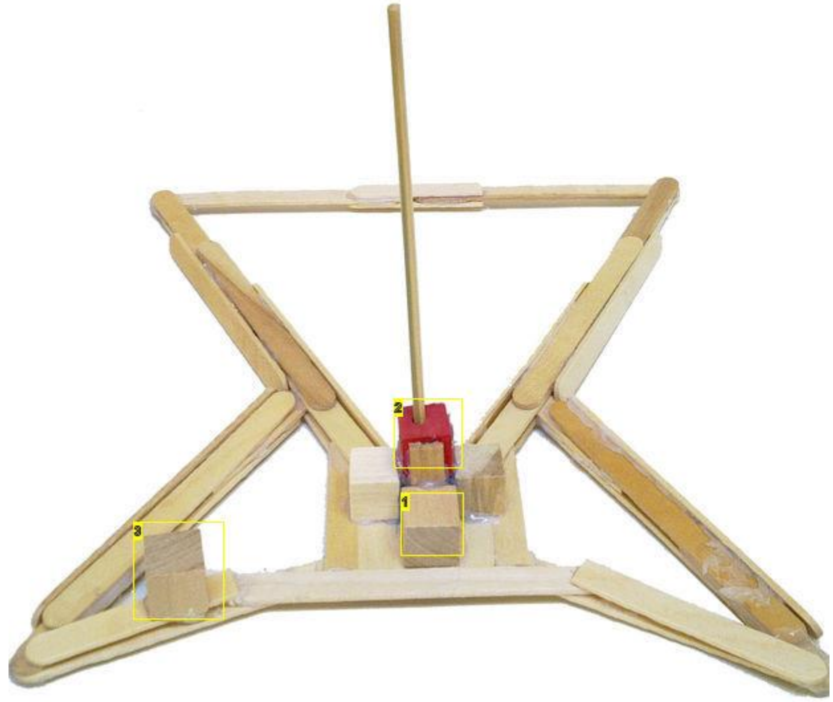
The Base

Image Notes

1.Additional cubes support the pivot

2. Two cubes with holes are stacked here to create the pivot. The skewer is glued in.

3.This cube elevates the piston that actuates the pivot. The position of this cube doesn't have to be exact as long as it is behind the pivot and a few inches awav.



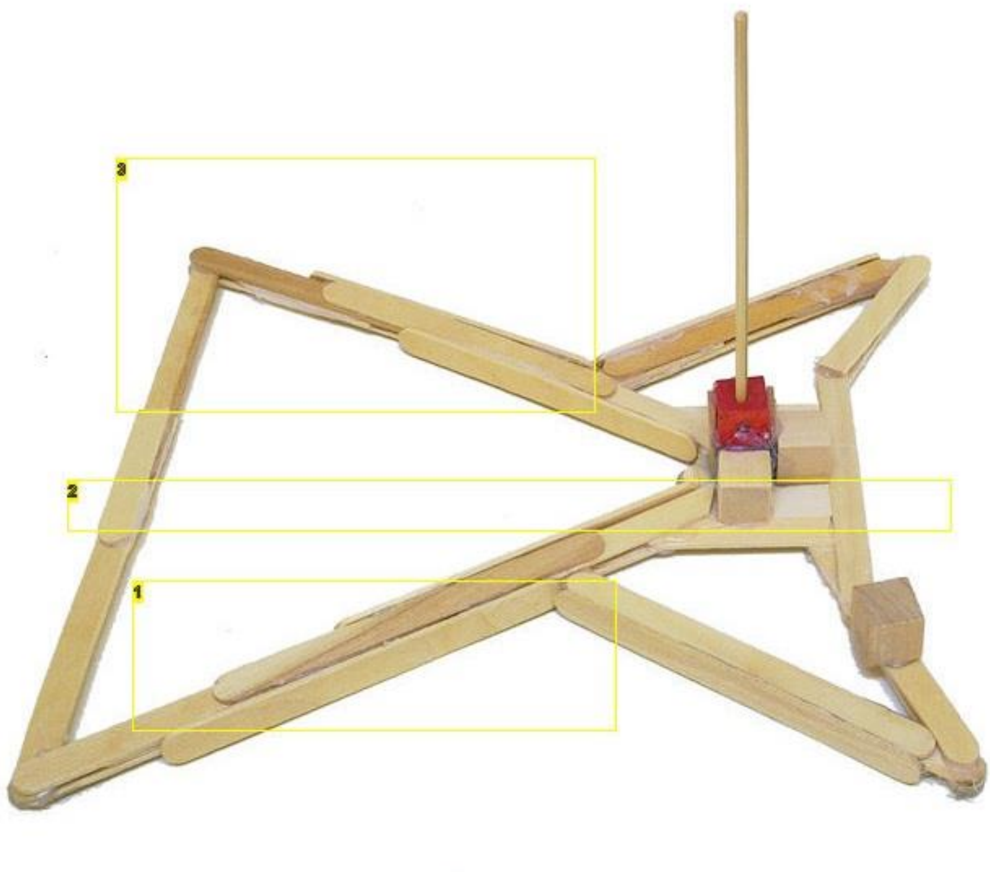
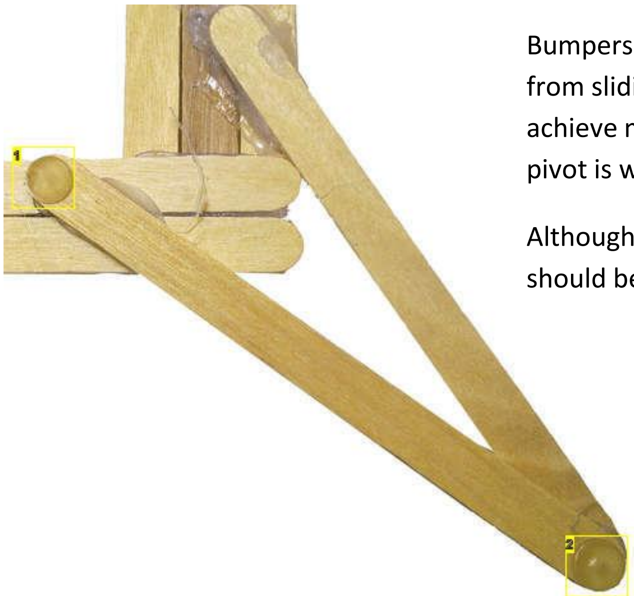


Image Notes

1. Base should be heavy, rigid, and low to the ground.

2. Students should strive to make a base that covers almost the entire 10-square inches

3. This is just an example of a shape that the base can take. Students are welcome to experiment (and redesign to make it better after battling!)



Bumpers are placed under the base to prevent the bot from sliding around. Position your bumpers carefully to achieve maximum stability (for example, under the pivot is where the most weight is sitting)

Although the bumpers have an adhesive backing, they should be glued on.

The Stand

Image Notes

1. Pivot column is built around two cubes with holes.
2. Insert a skewer through these cubes with holes during construction to ensure that the holes are aligned.

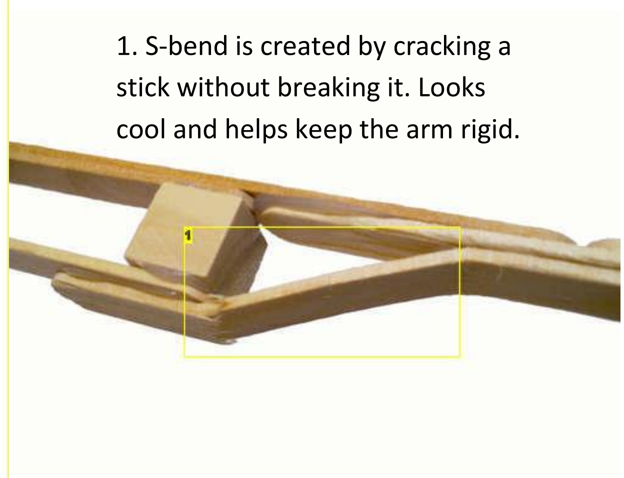
Image Notes

1. The piston that actuates the pivot column will connect to this cube.
2. 'V' shape in the back adds stability and makes the stand look better, but it isn't necessary.

The Arm and the Wedge

Image Notes

1. The arm can be any length and shape. This one is about 18" long. This design that uses two cubes and 14 sticks is very rigid yet lightweight.
2. This cube (red) attaches to the top of the stand.



1. S-bend is created by cracking a stick without breaking it. Looks cool and helps keep the arm rigid.

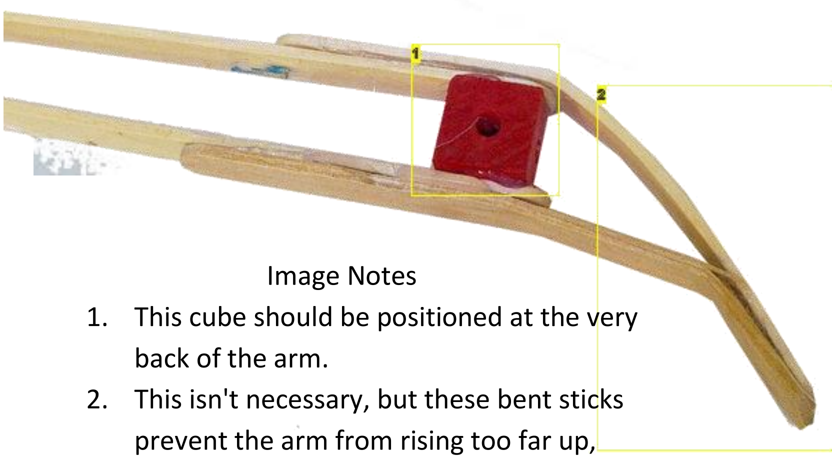


Image Notes

1. This cube should be positioned at the very back of the arm.
2. This isn't necessary, but these bent sticks prevent the arm from rising too far up, which helps to avoid accidentally flipping one's own JudoBot backward.

The design of the wedge is a crucial since it will determine how effective your bot is at getting under the opponent. The tips of the wedge should touch the arena surface when the arm is lowered completely. This wedge is just an example.

Assembling the pieces

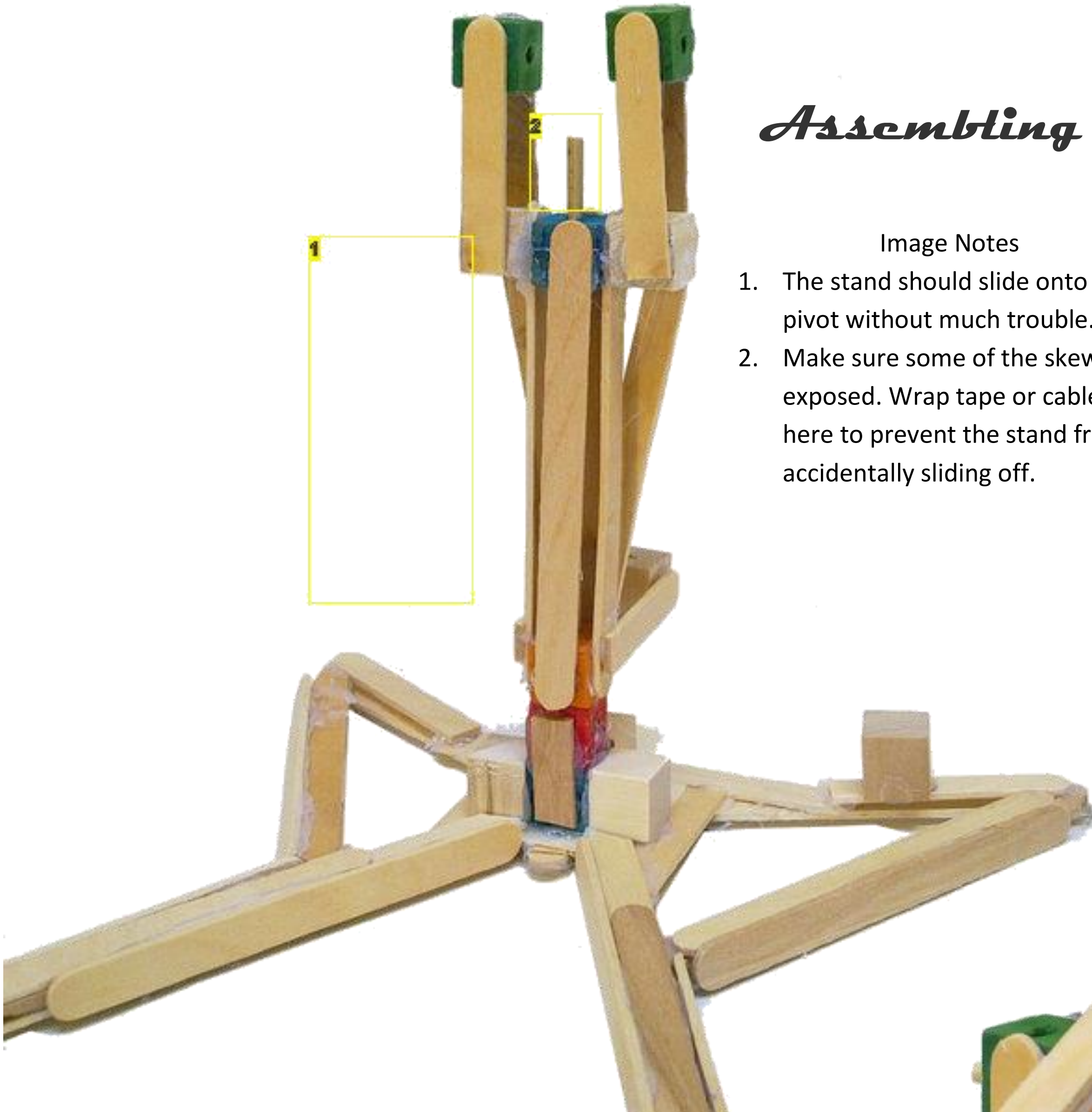


Image Notes

1. The stand should slide onto the pivot without much trouble.
2. Make sure some of the skewer is exposed. Wrap tape or cable ties here to prevent the stand from accidentally sliding off.

Use another small piece of skewer to attach the arm. Again, wrap tape or cable ties around the ends here to prevent the skewer from sliding out.

Make a hydraulic system

This part can be a bit tricky for students. Although the process is fairly simple, it isn't easy to commit to memory by watching it done once or twice. If you are a visual learners, watch the video at http://www.instructables.com/id/Hydraulic-JudoBots/step6/Make-a-hydraulic-system/. For students, you may want to outline these steps on a whiteboard:

1. Connect tubing to one syringe
2. Fill completely with water
3. Point the tip of the syringe up and push on the plunger. This expels all of the air and fills the tubing with water
4. Refill halfway and set aside
5. Submerge the tip of the second syringe and repeatedly pump the plunger to expel air. Fill halfway
6. Connect the syringes and try it out. If the total amount of water in either syringe exceeds the 10ml mark then there is too much water in the system. There should be little to no air bubbles, too.
7. Glue on a holed cube to the end of one plunger in each set

For extra fun, use food dye to color the water, though it's not necessary.

Image Notes

1. Tubing is cut into 2' lengths
2. Holed cube is glued onto the end of one piston in each system

Attaching the Pistons

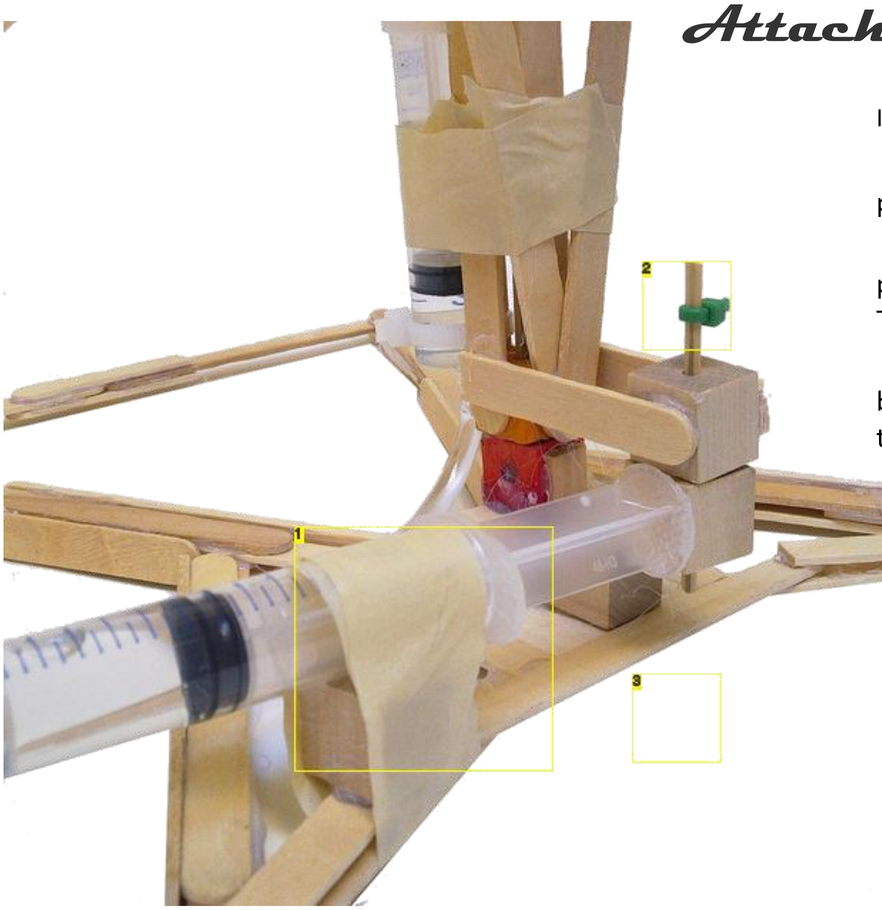


Image Notes

1. Calibrate the pivot by setting the piston to 5ml. Face the stand forward.

2. Align the cube on the end of the piston under the cube attached to stand. Tape the pivot piston to the base.

3. After the piston is taped to the base, insert a small piece of skewer through these cubes.

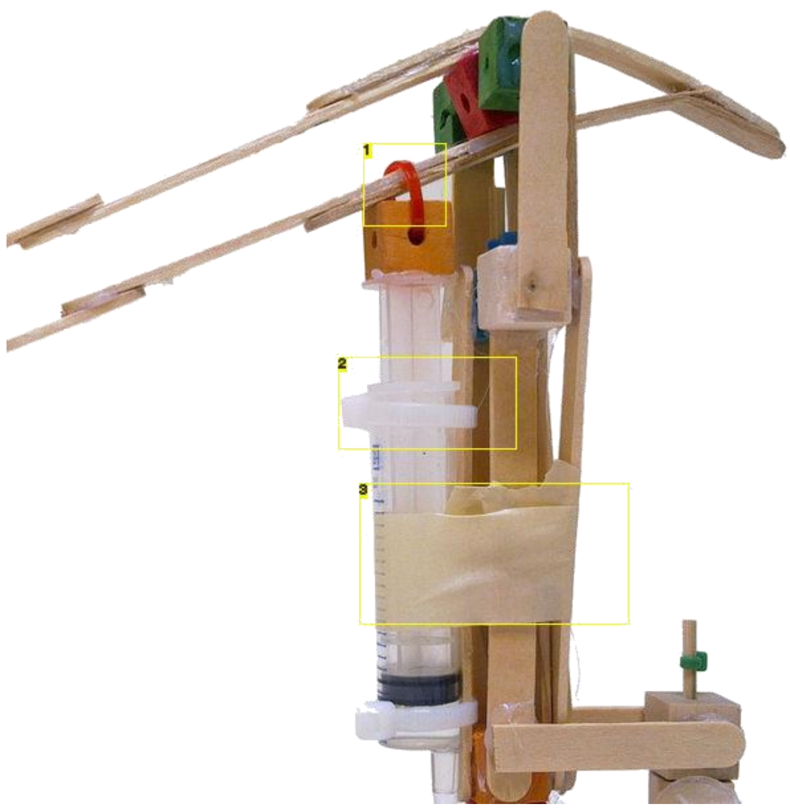


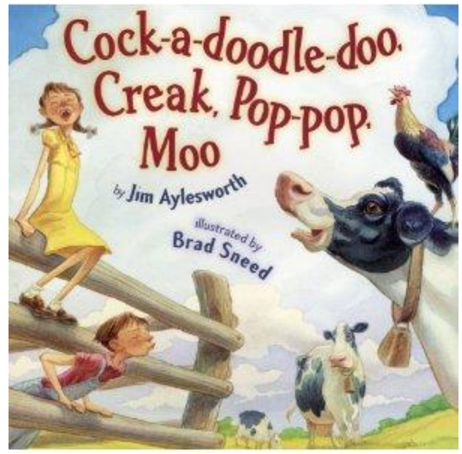
Image Notes

1. Use a cable tie to secure the arm piston to the arm itself. This tie shouldn't be too tight.

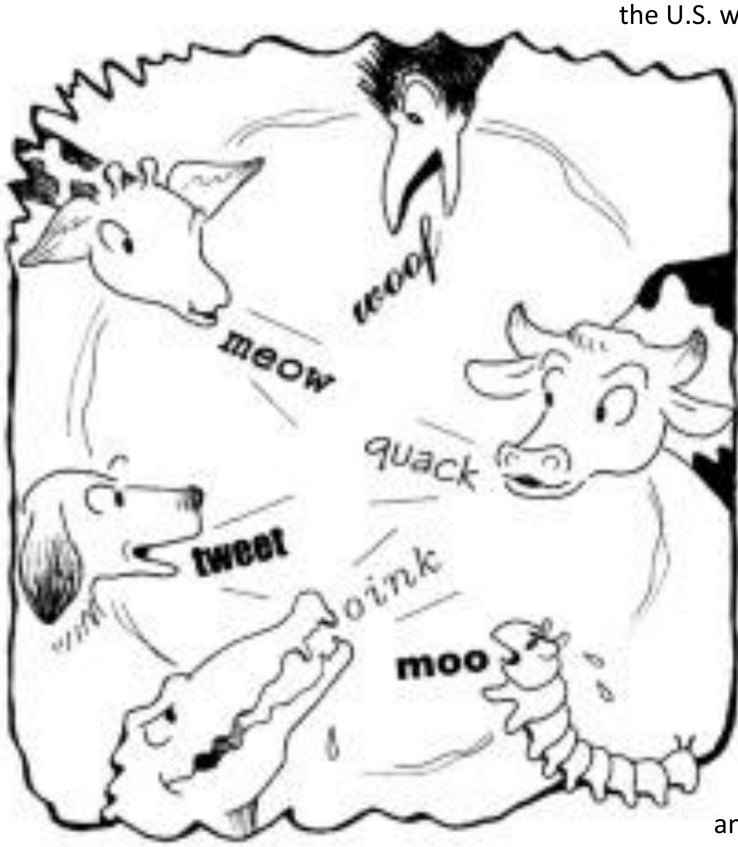
2. Tie a cable tie around the pivot column and the piston. Calibrate the arm by setting the piston to 0ml. Slide the piston down the column until the wedge touches the table. Tighten the cable tie.

3. Once the arm is calibrated, use a piece of tape to prevent the piston from sliding around.

Hydraulic Verse



To introduce this and provide samples for students, you may wish to find examples of onomatopoeia related books and poetry such as the fun *Cock-a-Moo-Moo* by Juliet Dallas-Conte and Alison Bartlett, *Cock-A-Doodle-Doo, Creak, Pop-Pop, Moo* by poet/author Jim Aylesworth *Nest, Nook, & Cranny* by Susan Blackaby poems by Jack Prelutsky, Shel Silverstein, or some of those in *Builder Goose* : *It's construction rhyme time*! by Boni Ashburn. Or pick from your favorite onomatopoeia filled books such as, *It's Almost Time* – written by Debbie Bernstein LaCroix and illustrated by Sarah Chalek, or *Snow Sounds: An Onomatopoeic Story.* There are many possible choices!



People in different countries describe the sounds that animals make differently. For example, here in the U.S. we describe the sound a rooster makes as "cock-a- doodle-do." However, some Europeans describe the sound as "coo-coo-ri-coo" and in Mexico Spanish speaking roosters say, "*kikirikí, ki-kiri-ki*." Or, take the humble frog in the US he may say, "ribbit" but take that same frog to France, and he says "*coa-coa*." Take him to Korea, and he says "*gae-gool-gae-gool*." And in Argentina he says "*¡berp!*"

It's all Onomatopoeia! (ON-OH-MAH-TOE-POE-EE-AH). Many times onomatopoeia words are completely made up, like describing a scraping noise as "sccrrettt." Other times people have used the sound word so much, it's become an "actual word" as in the case of noises like "hiss," "cluck," "peep," "slurp," and "meow." Cartoons make use of onomatopoeia with words like "Kaboom, Blam, Boom!" Remember, "Jingle bells, jingle bells...", "Baa baa black sheep have you any wool?", or "Twinkle twinkle little star..."?

Onomatopoeia is a relatively easy concept for students to understand. The difficult part is for students to understand the definition. Using the poem, “The Fourth”, by Shel Silverstein, can be a good introduction.

Before reading the poem aloud, it may be beneficial to discuss the meaning of the word onomatopoeia. Write the word on the board, this is a fun word, let the student's attempt to sound it out! After they sound-out the word with your help, discuss the meaning of the word.

Onomatopoeia:

1 : the naming of a thing or action by a vocal imitation of the sound associated with it (as buzz, hiss)

2 : the use of words whose sound suggests the sense

Next, let the student's individually, or as a group, to create a list of onomatopoeia's using the included ABC Brainstorm sheet. For instance, *Bam! Zap! Wam! Bonk! Crash! Bang! Pop! Zip! Zoom! Clash!* (Further examples: *bang, bing, buzz, crackle, clang, clatter, creak, ding, dong, fizz, glug, growl, grunt, gurgle, howl, hum, knock, meow, moan, murmur, neigh, oink, ping, pong, pop, plop, rattle, rip, roar, slap, smack, snap, squawk, thud, tweet, wham, whiz, whoosh, yawn, yelp*, and so on.)

Use brainstorming to combine and extend ideas. Creativity comes from a blend of individual and collective "ideation." Have students follow the four rules of individual or group brainstorming:

1) Don't allow criticism; 2) Encourage wild ideas; 3) Go for quantity; 4) Combine and/or improve on others' ideas.

Although it can be a fine line, try to help students to not confuse onomatopoeia words with a word that just states the fact a sound was made. As in, “laugh” – sure, a laugh IS a sound, but the words that imitate the SOUND of laughing are, “ha ha ha!”

The next step is the read a poem or two, like the following, out loud. Poetry's cool — and a lot of fun! Ask the student's if any of Silverstein's or Prelutsky’s onomatopoeia's were their list; let them find any.

"The Fourth," by Shel Silverstein.

Oh
CRASH!
my
BASH!
it's

BANG!
the
ZANG!
Fourth
WHOOSH!
of
BAROOOM!
July
WHEW!

Real World Examples: Memorable "Mmm" Makes Money!

Don't discredit the power of onomatopoeia. Can you remember an old jingle for Alka Seltzer that goes a little like this?

Plop plop,

fizz fizz,

Oh, what a

relief it is!

Can students think of any other jingles that use onomotapeia? (*Mmm*, *mmm*, good?; Click it, or ticket) Consider Rice Krispies cereal. Their main slogan is *snap, crackle, pop*. This is a perfect example of onomatopoeia. It reflects the unique sound the cereal makes as milk is being poured over it. Marketing execs picked up on this sound and decided to make it the sole focus of their advertising campaigns. Their tactic was very successful, as Rice Krispies is one of the most popular cereals eaten around the world. Not only does it taste good, but it also offers a bit of entertainment, even if it's for a second. Sure, adults may not appreciate the snap, crackle, pop, but young kids do.

Their Turn

Ask your students to try to describe a sound they hear every day related to hydraulics--the sound of the wind, the *booming* sound of their heartbeat after they've run, the rain, the *beep…beep* of a dump truck, the soft motor rumbling "*putt puff puttedy chuff*" of a tractor, the *swish-swash* of dishwasher, a train ("choo choo" is one way to describe the sound) and list them on the board.

Word Warm-Ups: Just as you would stretch before you go running, students need to warm up before they start writing poetry. Here are a few favorite exercises to help you and your students stretch your minds:

1. **Word Play**
   Have students pick a word, any word on the board, and as a group think of all the words that rhyme with that word. Try first with one-syllable words, and then with words of two or more syllables.

2. **Object Observations**
   Pick an object they chose— a tractor, a dishwasher, you — anything. Then have students write down everything they notice about that object.

3. **Synonym Silliness**
   Think of an adjective, such as happy, soft, tall, or sleepy. Then write down all the words you can think of that have the same meaning as that adjective. This list will help a lot when you're trying to describe things.

Now that students are warmed up, have them write a poem incorporating the sounds, observations, they/the group made, along with words from their ABC Brainstorming sheet. Since poetry is highly auditory, playing with sounds teaches children to use one of their five senses to explore and explain the world!

If the kids are younger, or for further practice with older students, write a sample poem as a group, have each child add one word that you write on a big sheet of paper in front of everyone. Remember the four rules of brainstorming.

Whatever the method, your students' poems should describe the sounds and also where the sounds "take" them.

For example, discuss:

- What does the sound call to mind?
- How do they feel when they hear the sound?
- What does the sound seem to be "saying"?

Sound poems written by kids are often fun to read. However, rhythm can be a problem for some students, many times the rhythm for the two sound poems above from the sounds themselves. Younger elementary students will probably find it a lot easier to get started writing a sound poem if they follow the rhythm and rhyme pattern of the poem below:

Tick tock, goes the clock. (A)

Bow wow says the dog. (B)

For Those That Struggle

The first thing students must learn is that they have something to say. "I have nothing to write about," or, "I don't know anything." How many times have you heard that come out of your students or your own mouth? That is simply not true.
The best way to get kids writing? Talk to them. Have a conversation, get them speaking and talking about their subject, their thoughts, their ideas. Then when they're excited and eager to share something, an idea, a thought, a bit of knowledge, tell them, "Tell me about it…" and when they start to speak, say, "Write it down. I really do want to hear all about it, but I need you to write it down. Just like you're talking to me, right now."

And when you come back, keep the conversation going, discussing the words they've written, and the story they're telling in their poem, letting them know what you like and what you'd like to know.

Quack quack says the duck. (C)

Croak croak says the frog. (B)

This poem has a very simple rhythm and rhyme scheme that most lower-grade elementary-school children should be able to follow:

DUM DUM, da da DUM (A)

DUM DUM, da da DUM (B)

DUM DUM, da da DUM (C))

DUM DUM, da da DUM (B)

It may be best to start with this exercise and then see what other rhythm and rhyme patterns pop into your students' heads. Ask each student to illustrate their poetry with pictures. It may also be fun to show children examples of comic book art that shows onomatopoeia's in large, outlined font. Encourage students to add their onomatopoeia's into their art as well!

Revising Guidelines

By now, students should have a first draft of your poem, which means they're ready to begin revising. Provide opportunities for students to read their writings out loud at the end of every writing session, maybe just to you, maybe to the whole group. Encourage the other students to listen quietly to the reader and then ask more questions about the poem that interest them. The author will hear the flaws in their own work as they read it verbally. It will bother them enough that they'll want to improve the words so they sound better. And THAT'S where the mechanics naturally come into play. Children are open to help with spelling and handwriting when they know they have something to say and teach. Mechanics and spelling problems, while incredibly important, must be secondary to the act of communicating information.

When they've come to care about the words that are on their paper is when mechanics come into play. When they want it to not only sound good but look good as well. That's when you teach the more advanced writing technique concepts to show them that there are millions of ways to manipulate words to get exactly what they want out of them.

Show students how many fun ways there are to add depth to their work (synonyms, super adjectives, adverbs, antonyms, vivid verbs, punctuation changes, etc) so that others will cherish what they write and the information they share.

Let them know that rewriting is often the most important part of writing because hardly anything ever comes out right the very first time. Here are some guidelines that can be helpful when students begin revising their poetry. Encourage them to:

1. Rewrite their poem at least once. Many professional poets rewrite most of their own poems at least four or five times. Some have even rewritten them as many as 100 times!
2. Don't rush! Poems can take as long as a week, a month, or even a year to write.
3. How will they know when their poem is done? Often the poem lets you know when it's done. It's just like being full when you eat. Sometimes if you take one more bite, you get a stomachache. But, if you don't take that extra mouthful, you'll feel perfectly satisfied. Well, it's the same with poetry — they'll just know when it feels right.
4. When students get frustrated, and feel that the poem is not coming out the way they'd like, have them put it aside and do something else for a while, work on illustrations, or work on another poem!

When they're happy with what they have written, have them share their final illustrated draft!

ABC BRAINSTORMING

Student: ______________________________ Topic: ___________________________

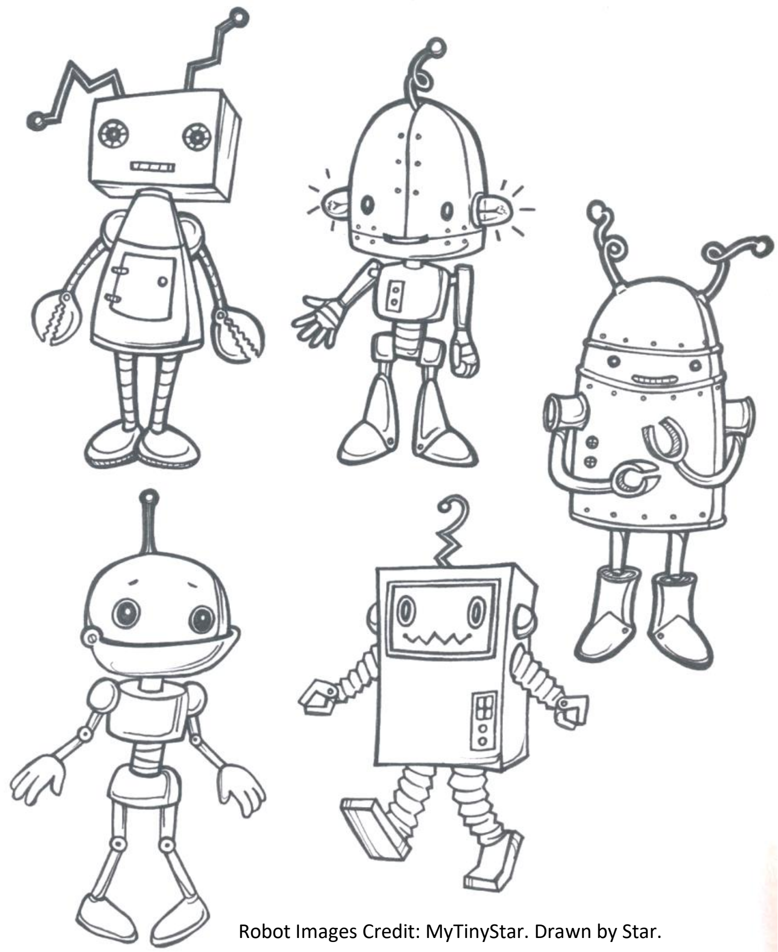
A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P
Q	R	S	T
U	V	W	XYZ

Fluid I-Draw-Its!

A fun way to introduce this section is with, Frank n Stan by M.P. Robertson. Now that students have built robots with fluid power, have students paint mechanics, with fluid! All successful watercolor projects begin with a great drawing and robots are great fun to draw and paint.

Materials:

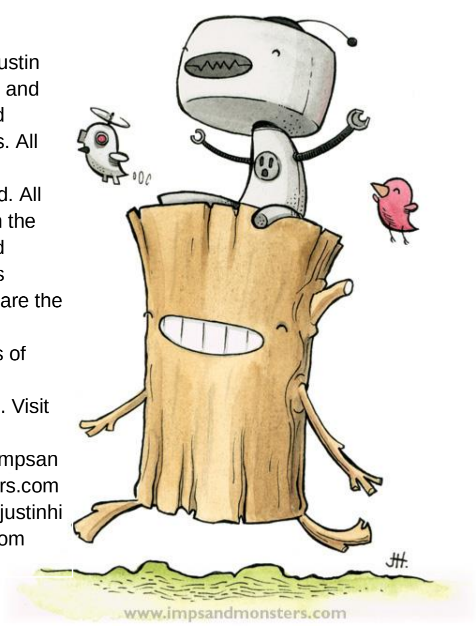
- Oil Pastels (dark colors) or crayons
- Liquid watercolors or pan style
- Paper
- Cheap Watercolor paper
- Paintbrushes
- Salt (optional)
- Cotton Swabs (optional)
- Rubbing Alcohol (optional)
- Condiment cups with lids (for extra paint storage and supplies)



Robot Images Credit: MyTinyStar. Drawn by Star. http://blog.mytinystar.com/2010/06/robots-hims-and-hers.html.

Optionally, start with a directed line drawing of a robot. It's important to note that even though you may use, "directed line drawing", it's rare that you want to give your students just one option, most of the time you'll end up with many drawings on the white board. Look at pictures and brainstorm together what a robot can look like, and create sketches up on the board. Give lots of examples!

Image Credit: Robot and Log.
 All works on the Imps and Monsters Website are the original creations of Justin Hillgrove. Visit the artist at www.impsandmonsters.com or www.justinhillgrove.com



Encourage the children to think about what elements a robot may have. Brainstorm lots of fun ideas and as the children call out things like rivets, wires, solar panels, draw these things on the board. Demonstrate various ways to draw robots using pictures, books and drawings as guides. Stress the importance of working through "mistakes" and having fun with an unexpected line. Draw a few different ones; some realistic, some silly, some animated, then talk with students how you could change the wings, the shape, that sort of thing. This technique works well, as you want the children to learn to draw but also want them to be as individual as possible.

In the process of drawing on the white board, always incorporate mistakes. Always! Laugh at your "mistakes", tell the kids to expect them and then show them how to turn mistakes into something else. It's critical that you show your artistic side, no matter what you privately think of it, and inspire your students

Then have the kids get busy drawing their own robots with an oil pastel, crayon, or a waterproof marker (though the way non-waterproof markers bleed when exposed to water can make some cool effects), etc. Once the drawing is complete, emphasize large shapes, set out a palette of watercolor paints.

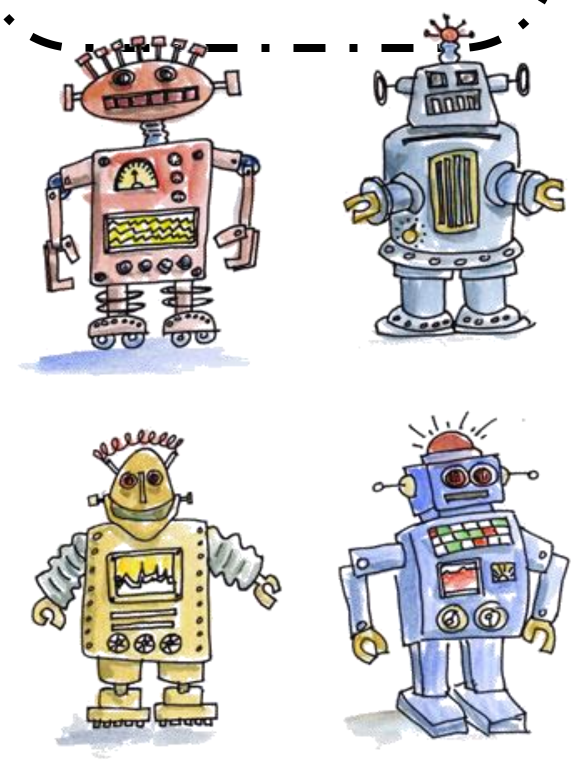
Watercolor Painting Techniques:

- *Oil Pastel/Wax Crayon Resist*: If they want their outlines of the robot to show through, oil pastel will repel the paint, create clear outlines, and allow the drawing to show through the paint. Note: Wax crayons can also work for this, but aren't quite as clear, though they are also a lot less messy.
- *Drip Drop*: Rubbing alcohol is delightfully unpredictable, like watercolor itself. If you have rubbing alchohol and cotton swabs, alcohol and watercolor don't mix well, but they make some some amazing effects. Dipping a Q-tip into the alcohol have students proceed to tap and drip alcohol directly into the washes. As the alcohol hits the wash it repels the paint, pushing it away while leaving a lighter tint of the wash exposed. The results of their fight on the paper is strangely organic in nature and not achievable using any other technique.
- When they're ready to paint, have students paint the background and its details first and spend some time making the colors ooze and blend together on the page.
- If they used oil pastels or wax crayons, students don't need to avoid painting near or on the outlines, as the watercolor paint will bead off the oil pastel/crayon. Encourage the children to mix paints on their paper, not in paint palettes, and use the

Teacher Tip!

Ban pencils and erasers.

Sounds harsh, right? It's not being mean, the reason is purely practical: small pencil leads encourage small drawings. If a kinder is drawing a robot and then is required to paint that very robot, using a pencil will surely lead to frustration. It's hard to paint teeny tiny eyes! There is another reason: pencil markings can be erased, which leads to second guessing, which leads to lots of eraser action, which leads to class being over before the child has anything on his paper. Using oil pastels, crayons, and/or waterproof markers allows the artist to move quickly, commit to the drawing and forgive their "mistakes". This is a big and very important part of creating art; giving into the process and not worrying about the details.



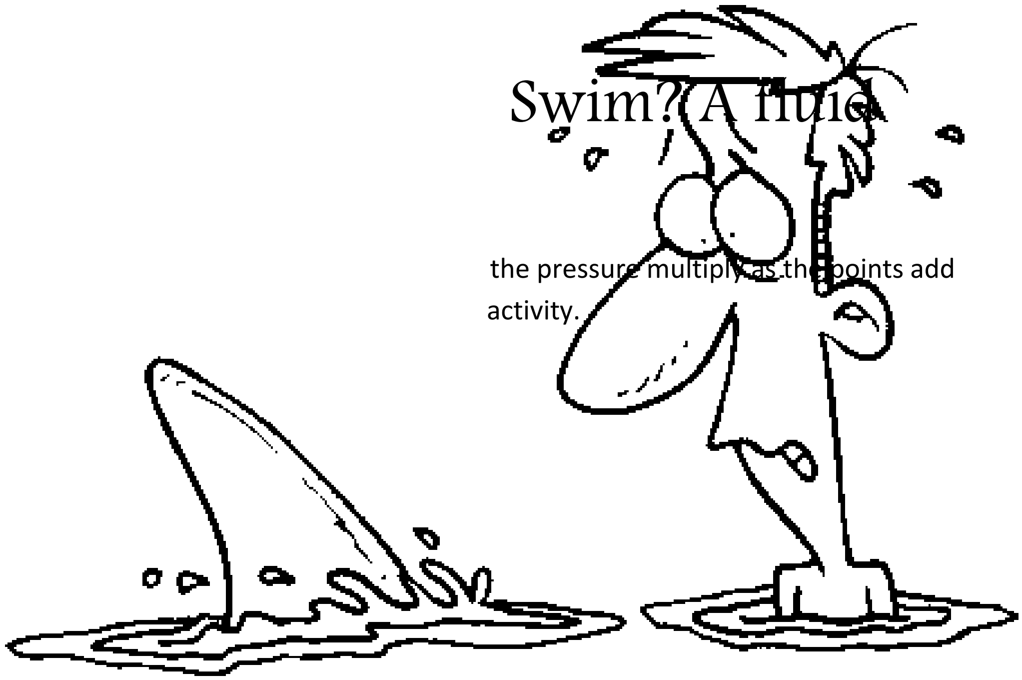
double-loading technique when you can. It produces very cool results and clean-up is much easier!

- *Wet-On-Dry Technique:* First, students dilute their pain with water and placing it onto the dry paper. The color lies on solid **without** gradient (Gradient is blending of shades from light to dark or from one color to another). Encourage students to work with quick and spontaneous strokes. Remind them that if they want crisp edges, they must wait for the paint to dry before painting next to it! Otherwise, they are using the following technique.
- W*et-On-Wet Technique*: Which is painting a wash of water (or paint), and then painting on top of that area while it's still wet with quick strokes. The result is a blended or blotchy and clouded effect with gradient.

Image Credit: Robot Dog Walker. ©2010 Justin Hillgrove and Imps and Monsters. All Rights Reserved. All works on the Imps and Monsters Website are the original creations of Justin Hillgrove. Visit the artist at www.impsandmonsters.com or www.justinhillgrove.com

Image Credits:Robots by Bina. Visit the artist to see other great art at http://binaviviensantos.blogspot.com/

Sink or Swim? A fluid review



Students get to feel the pressure multiply as the points add up in this fun review activity.

Materials:

- Lesson based review questions
- Math skill review questions and cards

Have students form two teams and line up in two lines across the room facing each other. Ask someone on team 1 a question, if they get it right they may “sink” someone on team 2.

Then I go to someone on team 2, if they answer their question right they may either sink someone on team 1 or rescue their "sunken" team member. This gets them using strategy and thinking about the end result and using strategy, is it better to rescue a high scoring teammate, or get the point right now? The kids really love this game. The winning team is the team with the most people still standing.

Sources and Resources

This lesson plan is a small window into the vastly intricate world of hydraulics and mechanics. I hope it will stimulate further exploration by students, and instructors, into the world of experts in the field, expand the boundaries of our thinking about the natural world and stimulate our imaginations. In the construction of this lesson plan I have been guided by, and recommend the following resources*:*

Brain, Marshall. "How Hydraulic Machines Work" http://science.howstuffworks.com/transport/engines-equipment/hydraulic1.htm

How to Make a Hydraulic Lift for a School Project | eHow.com
http://www.ehow.com/how_7724623_make-hydraulic-lift-school-project.html#ixzz283Lu2f1j

"Hydraulics." http://en.wikipedia.org/wiki/Hydraulics

Middle School Activities for Pascal's Principle | eHow.com http://www.ehow.com/list_5791550_middle-school-activities-pascal_s-principle.html#ixzz284Vha2mz

Instructables. WYE Lance. Easy Hydraulic Machines. http://www.instructables.com/id/Easy-Hydraulic-Machines/ Explore more projects that use simple hydraulic systems. Hydraulics made from plastic syringes and vinyl tubing are so easy to make and add an element of sophisticated movement to otherwise rather hum-drum projects

Science Guy. http://www.scienceguy.org/Articles/SyringeHydraulics.aspx

In the following video, Discovery Channel's "Massive Engines," host Chris Barrie demonstrates the concept of the hydraulic pump. The hydraulic pump was invented by Joseph Bramah during the Industrial Revolution. http://videos.howstuffworks.com/discovery/34870-massive-engines-hydraulic-pumps-video.htm

Some books that may go with some sections in the lesson, or show appropriate styles are:

- *Cock-a-Moo-Moo* by Juliet Dallas-Conte and Alison Bartlett,
- *Cock-A-Doodle-Doo, Creak, Pop-Pop, Moo* by poet/author Jim Aylesworth
- *Nest, Nook, & Cranny* by Susan Blackaby
- Poems by Jack Prelutsky, Shel Silverstein
- *Builder Goose: It's construction rhyme time!* by Boni Ashburn.
- *It's Almost Time* – written by Debbie Bernstein LaCroix and illustrated by Sarah Chalek
- *Boy and Bot* by Ame Dyckman
- *Frank n Stan* by M.P. Robertson