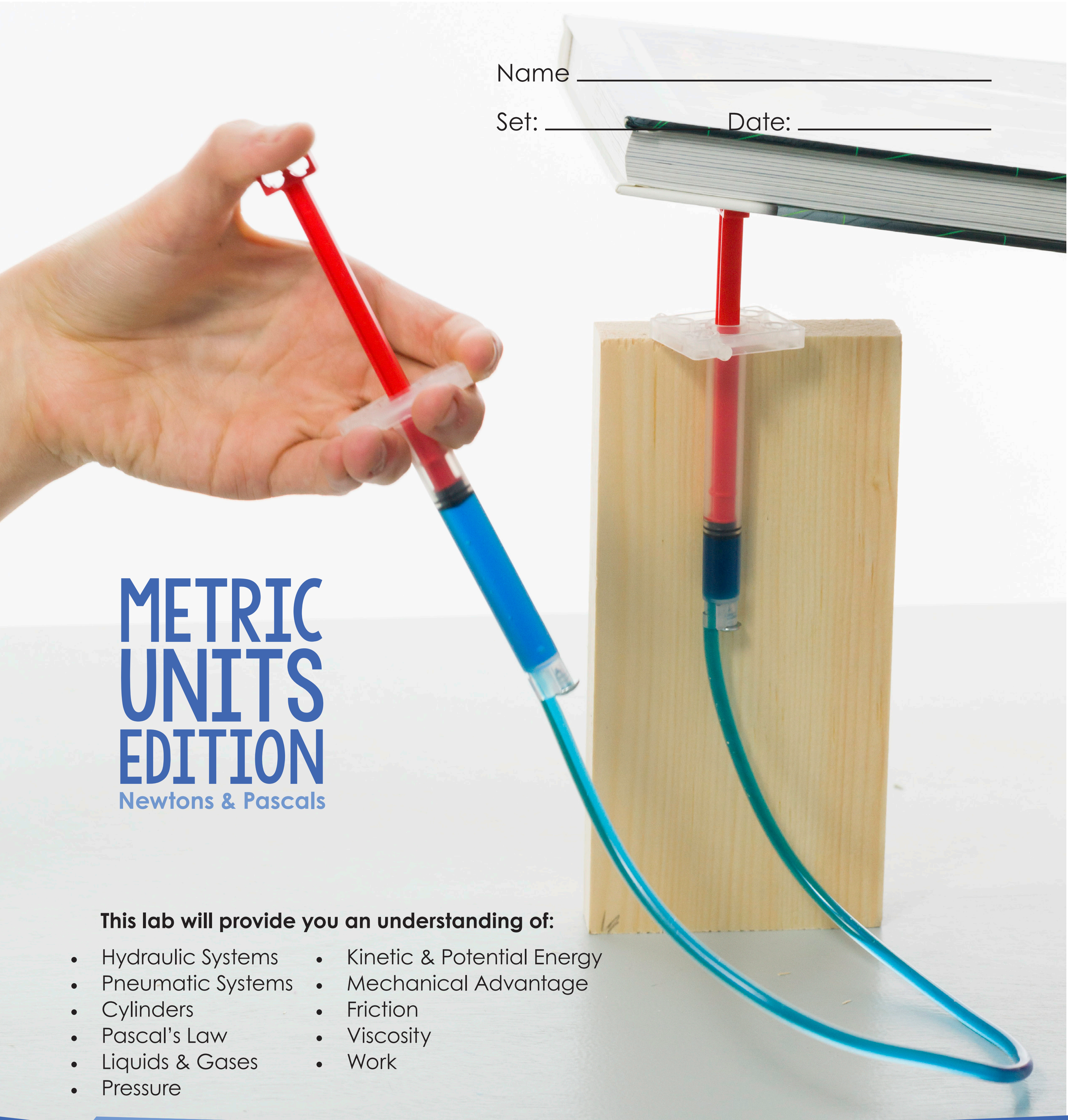
# FLUID POWER LAB



Name ____________________

Set: ____________ Date: ____________

# METRIC UNITS EDITION

## Newtons & Pascals

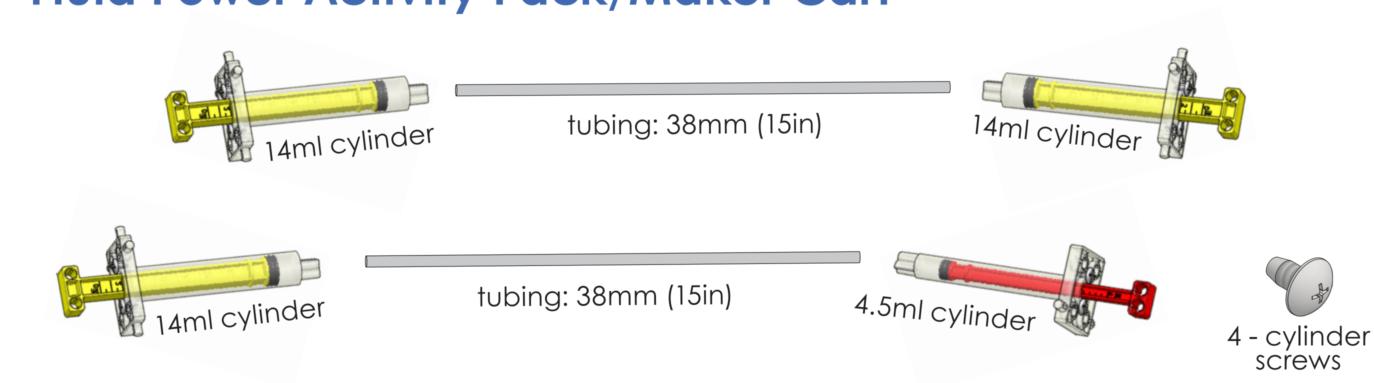
**This lab will provide you an understanding of:**

- Hydraulic Systems
- Pneumatic Systems
- Cylinders
- Pascal's Law
- Liquids & Gases
- Pressure
- Kinetic & Potential Energy
- Mechanical Advantage
- Friction
- Viscosity
- Work

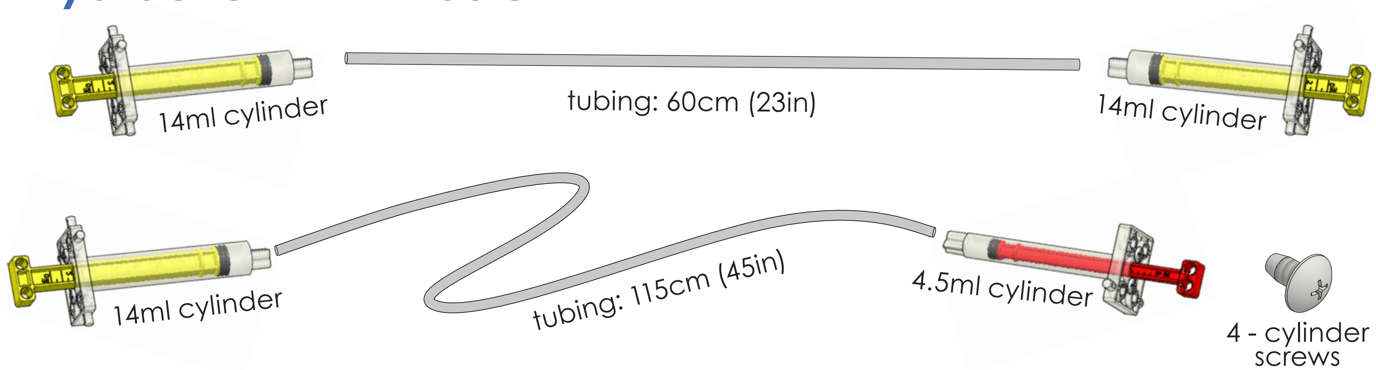
## TEACHERGEEK SUPPLIES YOU'LL NEED

Cut or find tubing the following lengths to use later in **Activity Build Guides** and **Design & Engineering Challenges**. Do not connect anything yet. First we're going to experiment a bit with pressure.

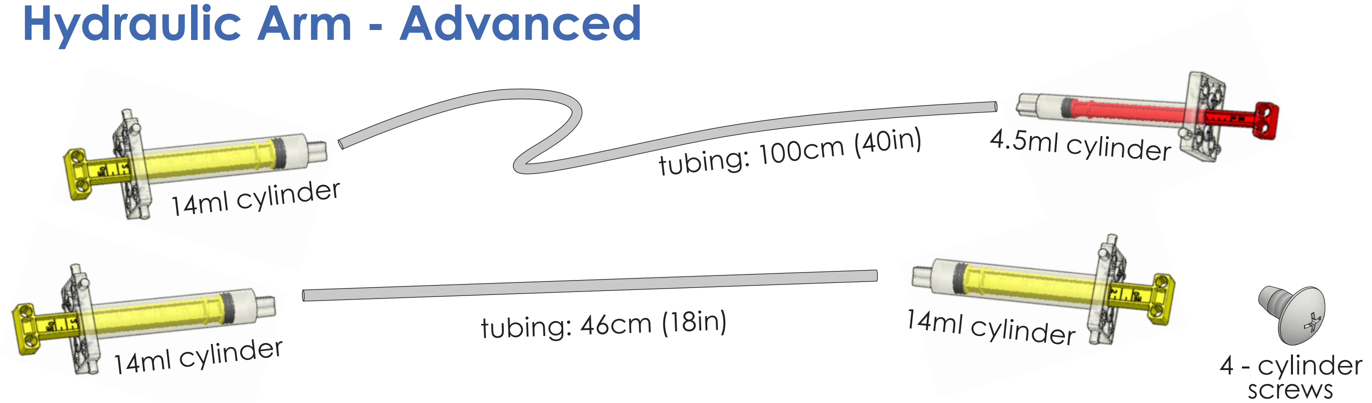
### Fluid Power Activity Pack/Maker Cart




### Hydraulic Arm - Basic




### Hydraulic Arm - Advanced




When it's time, refer to the end of this lab for help assembling your pneumatic and hydraulic systems.

# FLUID POWER

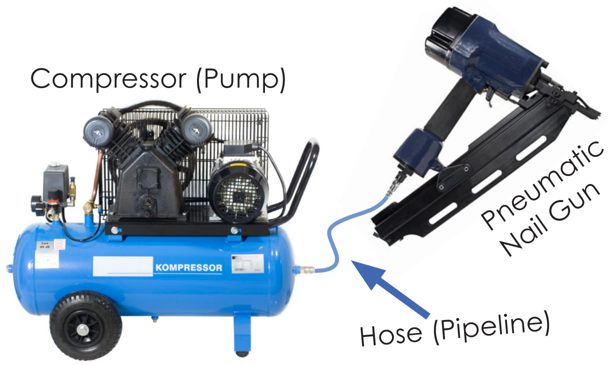
**Fluid power** is an area of technology dealing with the generation, control, and transmission of pressurized fluids. A fluid can be a **gas** or a **liquid**.

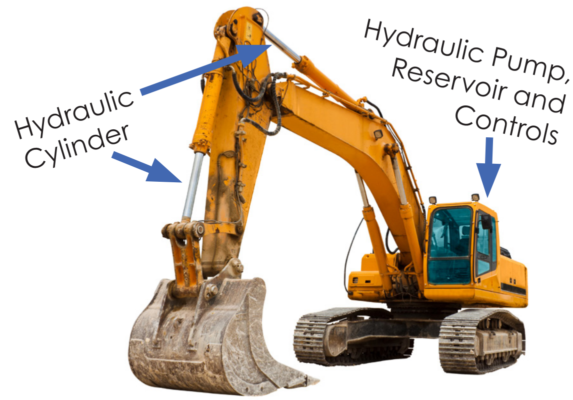
## PNEUMATICS

Pneumatic systems use a **gas** to transmit and store power.

## HYDRAULICS

Hydraulic systems use a **liquid** to transmit power.




## Pneumatic Devices

**1.** List two devices, other than the ones above, that use **pneumatics** for operation. Describe how they use pneumatics.

| Device | How does it use pneumatics? |
| --- | --- |
| ____________________ | ________________________________________ |
| ____________________ | ________________________________________ |

## Hydraulic Devices

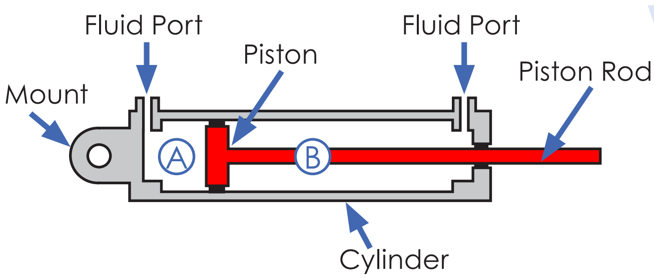
**2.** List two devices, other than the ones above, that use **hydraulics** for operation. Describe how they use hydraulics.

| Device | How does it use hydraulics? |
| --- | --- |
| ____________________ | ________________________________________ |
| ____________________ | ________________________________________ |

# CYLINDERS

Cylinders transform pressure and fluid-flow into **mechanical force**.

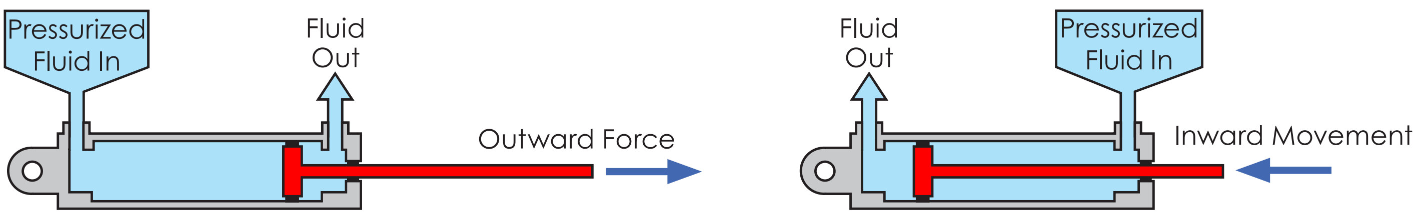
## Anatomy of a Cylinder




Chambers Ⓐ and Ⓑ are sealed, fluids can only enter or exit through the ports. Pressure in a chamber creates a force on the piston.

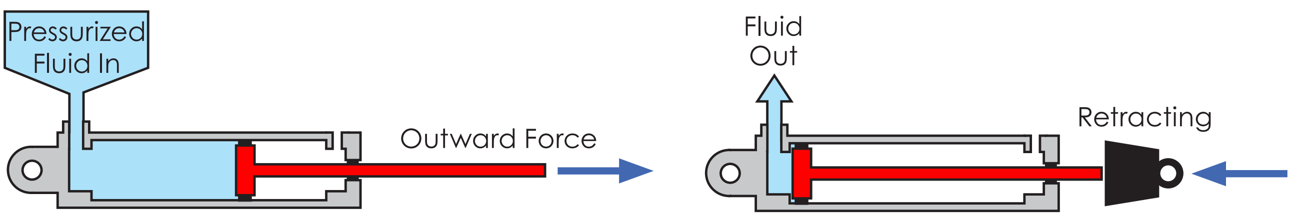
## Double-Acting Cylinders

Most cylinders are **double-acting**. Double-acting cylinders allow pressurized fluid to flow on either side of the piston, allowing it to be powered in both directions.

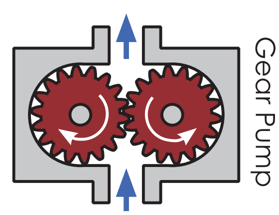



## Single-Acting Cylinders

**Single-acting** cylinders are only powered in one direction. The piston is returned by the weight of the load or a spring.

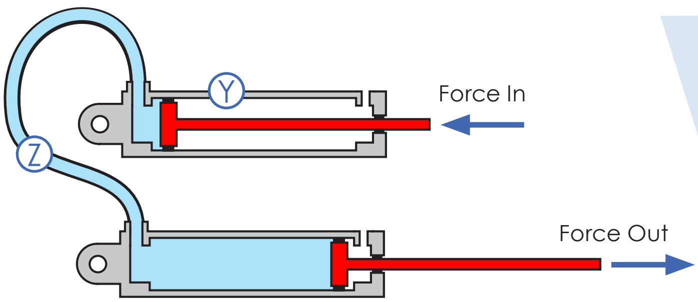



The pumps that power cylinders can usually only create a **positive fluid pressure** (push fluid). That is why most cylinders, like the ones shown above, are designed to only be powered by positive fluid pressure.



## Your Cylinders Will Push & Pull

You will use a cylinder as a pump. The cylinder will be able to **push** fluid (creating a positive pressure), or **pull** fluid (creating a negative pressure). This will allow your cylinders with a single port to be powered in both directions.




✓ the correct answers below:

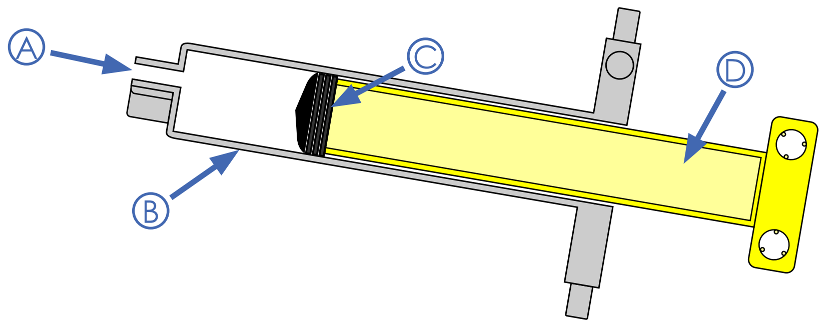
**1.** There is a ☐ Positive ☐ Negative pressure in line Ⓩ.

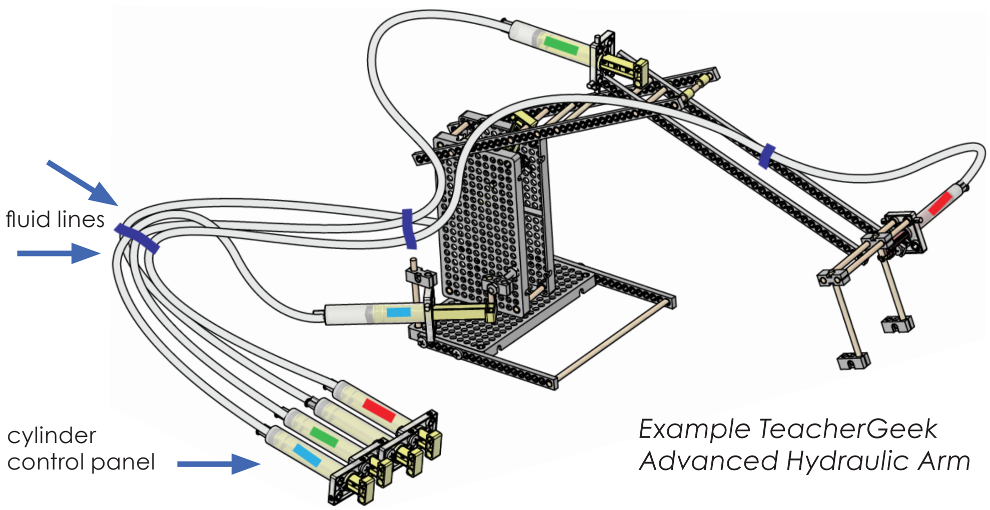
**2.** Cylinder Ⓨ is ☐ Pulling ☐ Pushing fluid.

## Know Your Parts

**3.** Match the components with their name by placing letters into the boxes below.

| | |
|---|---|
| Piston: | |
| Piston Rod: | |
| Cylinder: | |
| Fluid Port: | |




*Example TeacherGeek Advanced Hydraulic Arm*

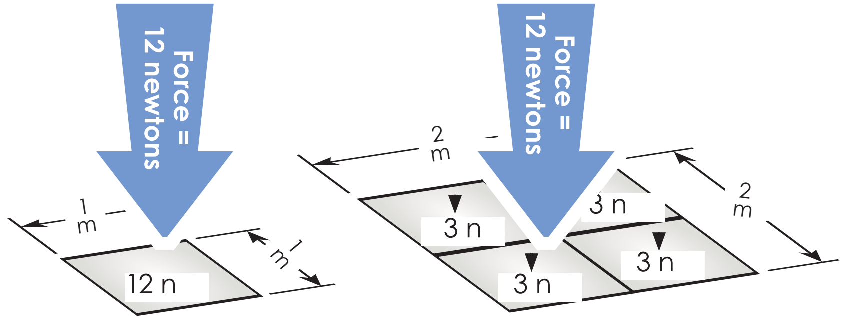
TeacherGeek

## WHAT IS PRESSURE?

Pressure is a force applied over an area:

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

The area over which the force is applied.




1m • 1m = 1m²

$\frac{12\ n}{1m^2}$ = 12 pascals

**Less Area** = More Pressure

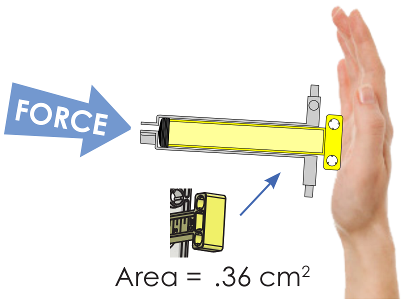
2m • 2m = 4m²

$\frac{12\ n}{4m^2}$ = 3 pascals

**More Area** = Less Pressure

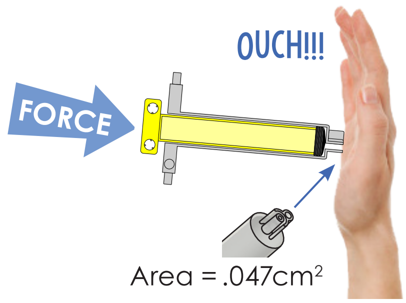
## Step One

Push the **piston end** of a cylinder against your hand.




## Step Two

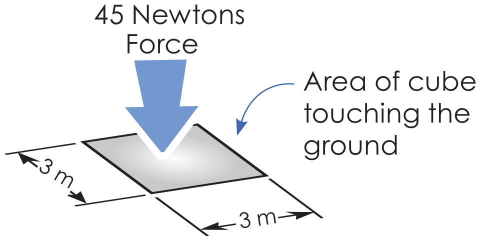
Push the **fluid port** end of a cylinder against your hand.




**4.** Both ends of the cylinder were pushed against your hand with the same force. Explain why they felt different? HINT: *Pressure = Force/Area*

## Putting Your Foot Down

A foot pushes down on a 3m³ cube with 45n of force.




**5.** How much pressure does the cube apply to the ground? Show your work.

Answer:

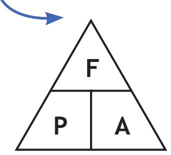
# FIND THE UNKNOWN

Let's look at another way to write the formula:

Use this chart to find the formula to calculate a **missing variable** (force, pressure, area).

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

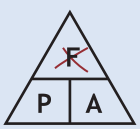
can be written as:




**P** = Pressure
**F** = Force
**A** = Area

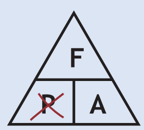
Cover the missing variable on the chart to find the formula to calculate it:

**You know:** Pressure, Area
**You need to find:** Force



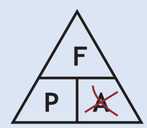

**Force = Pressure • Area**

**You know:** Force, Area
**You need to find:** Pressure



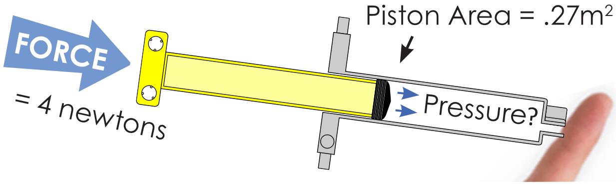

**Pressure = Force/Area**

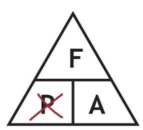
**You know:** Pressure, Force
**You need to find:** Area




**Area = Force / Pressure**

**6.** Pressure transfers between the piston and the fluid in the cylinder. Calculate the force of the piston when the fluid applies 20 pascals to it.




Finger trapping air in cylinder

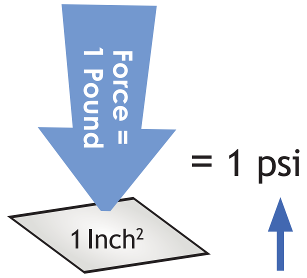
Show your work.

Answer: ____ pa

# MEASUREMENTS OF PRESSURE

## lbs/in² (psi)

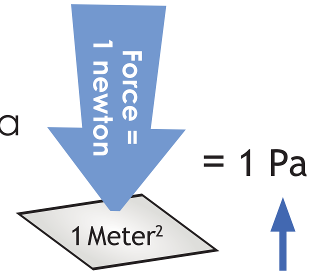
A force of 1 pound applied over an area of 1 square inch produces a pressure of 1 pound per square inch (1lb/in²)




pounds per square inch can be abbreviated as "**psi**"

## Pascal (Pa)

A force of 1 newton applied over an area of 1 square meter produces a pressure of 1 pascal.




Pascal can be abbreviated as "**Pa**"

# PASCAL'S LAW

**Pascal's Law:** a confined fluid transmits an externally applied pressure uniformly in all directions.

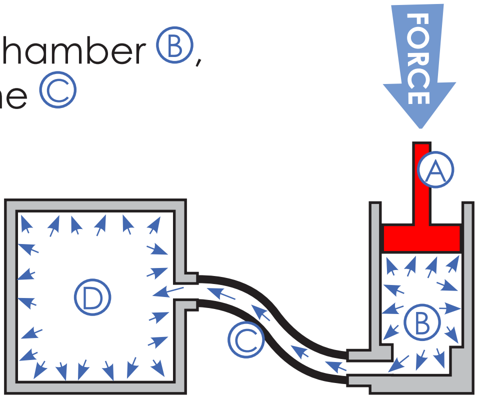
Piston Ⓐ applies pressure to the fluid inside chamber Ⓑ. The fluid transmits the pressure in every direction and to every surface it touches.

Squeezing a toothpaste tube is an example of **Pascal's Law**.

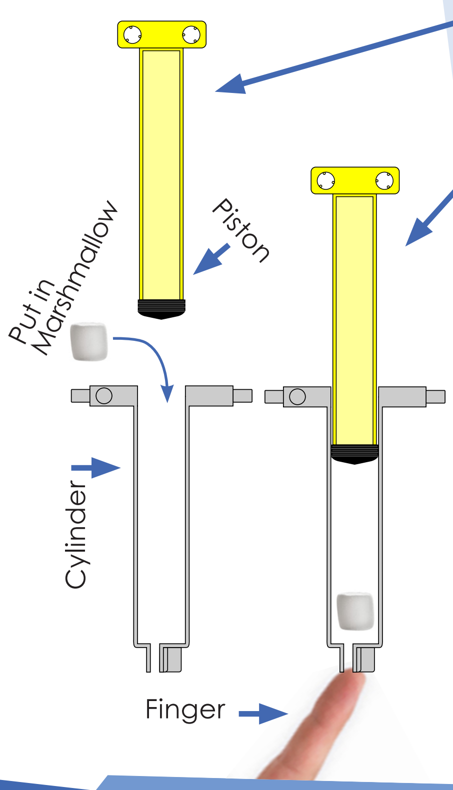
Squeezing applies **external pressure** to the toothpaste fluid inside. The toothpaste transmits the force equally **in all directions**, pushing paste out and making the tube walls bulge.

**7.** If the pressure is 5pa in chamber Ⓑ, what is the pressure in line Ⓒ and chamber Ⓓ ?

**Answer:** ______ pa




## Pressurizing Marshmallows




**A** Pull the piston out from the cylinder and place one small marshmallow inside the chamber.

**B** Push the piston in while covering the fluid port with your finger. *What happens to the marshmallow?*

**C** Push the piston in with your finger off the port.

**D** Put your finger over the port and pull the piston back. Watch the marshmallow.

**8.** What happened to the marshmallow?

______________________________

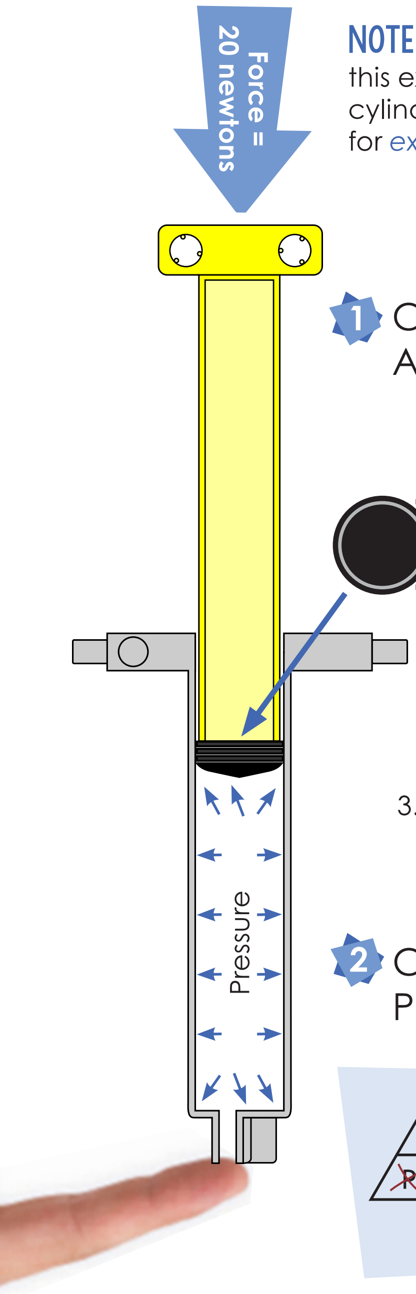
**9.** Why, according to **Pascal's Law**, did the marshmallow equally grow and shrink on all sides?

______________________________

______________________________

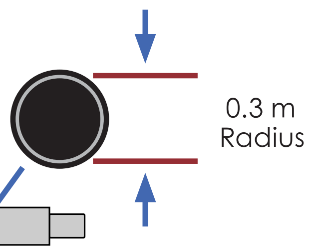
# CALCULATING PRESSURE

## Example Calculation




**NOTE:** Numbers used in this example are not real cylinder values. They are for *example purposes* only.

**1** Calculate the Area of the Piston




**Area = $\pi$ • Radius²**

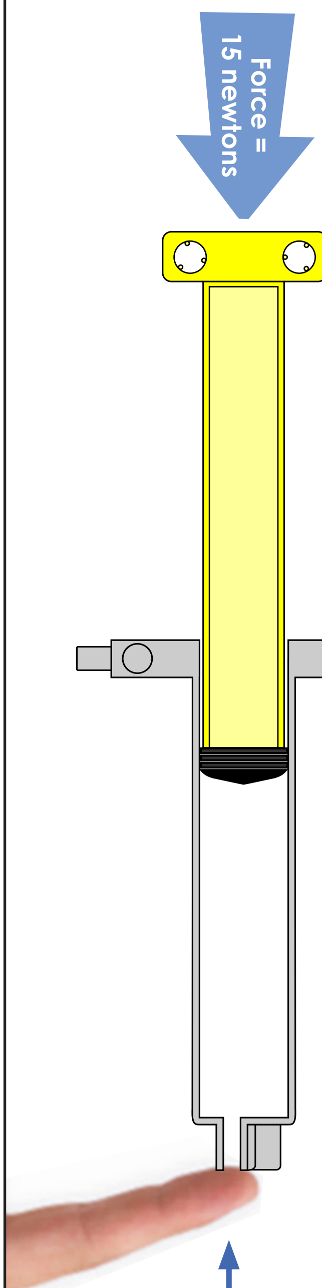
3.14 • 0.3m • 0.3m

*Area = 0.28 m²*

**2** Calculate Pressure

F / P A → $\frac{20 \text{ n}}{0.28 \text{ m}^2}$ = 71.4 pa

## Your Calculation




**10.** Calculate the pressure inside the cylinder.

**Formulas:**

Area of a circle = $\pi$ • Radius²

F / P A

**P** = Pressure
**F** = Force
**A** = Area

**NOTE:** Measure an actual 14ml cylinder and find the area of its piston *(do not measure the drawing on this paper or use the example area value)*.

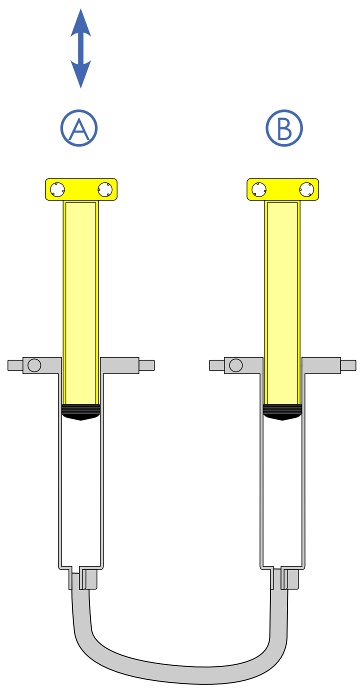
*Show your work below:*

Finger over tip so no air escapes.

Answer:

## PNEUMATIC PLAY

You will need a 14ml-14ml pneumatic system for this section.
Refer to the end of the lab for assistance assembling.




cut tubing length per activity instructions

TIP use colored water in hydraulic systems

### Push One Piston

Push and pull piston Ⓐ. Examine what happens and answer all the questions below.

Complete the following sentences using some of these words (words can only be used once):

**faster** **liquid** **slower**

**inversely** **transfers** **gas** **force**

**fluid** **solid**

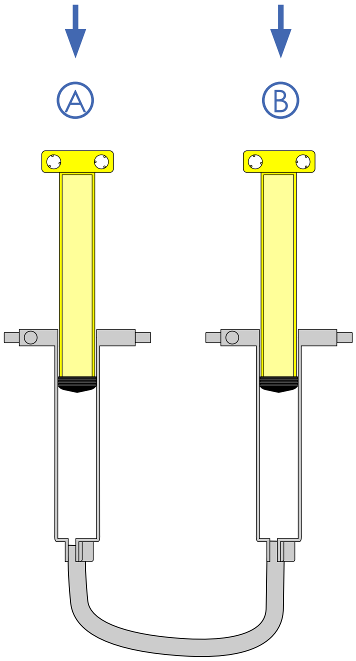
**11.** The pistons move ________ to each other.

**12.** Piston Ⓑ moves ________ than piston Ⓐ (the piston you pushed and pulled) due to air compressing.

**13.** The pressure applied by piston Ⓐ ________ through the ________ (air) to piston Ⓑ, applying a ________ that causes piston Ⓑ to move.

## PNEUMATIC PLAY

Use the same 14ml-14ml pneumatic system as before.




cut tubing length per activity instructions

### Push Both Pistons

Push and pull **both** pistons. Examine what happens and answer all the questions below.

Complete the following sentences using some of these words (words can only be used once):

**pressure** **force** **pascals** **potential**

**compresses** **kinetic**

**14.** An external [ ] is needed to move the pistons into the cylinders.

**15.** The pressure applied by the pistons [ ] the air in the cylinders and line.

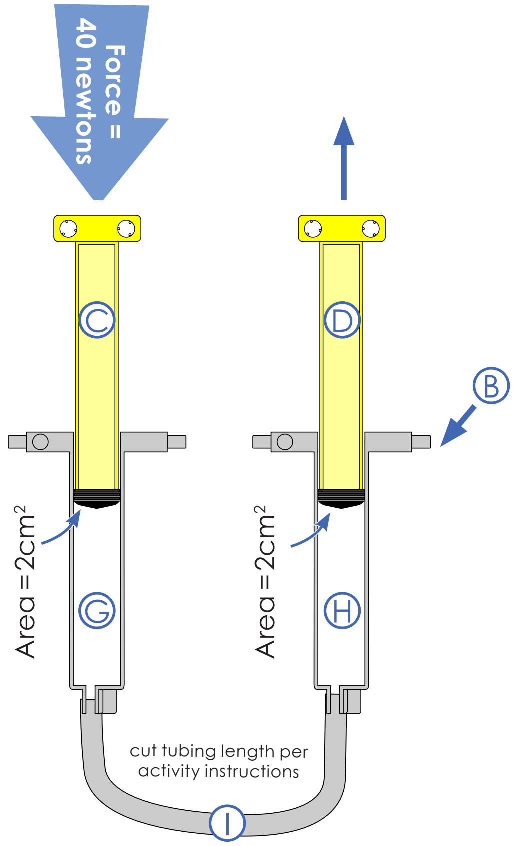
**16.** [ ] means the same thing as newtons/m$^2$.

**17.** Compressed air has [ ] (stored) energy.

**18.** After pushing both pistons in, quickly let go of one piston. The piston you let go moves outward with [ ] energy.

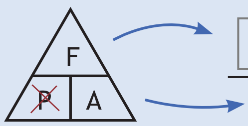
# SHARING PRESSURE & FLUID

How does fluid pressure transfer between cylinders? How can a force applied to one piston cause the other piston to move? Fill in the boxes below to find out.




## Piston C Applies Pressure

**19.** Complete the formula to find the pressure applied by piston Ⓒ:




[ ] / $2cm^2$ = Pressure

**20.** Pressure inside chamber Ⓖ = [ ] pa

## Fluid Transfers the Pressure

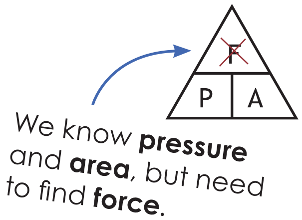
**21.** Pressure is transmitted from chamber Ⓖ through line [ ] to chamber [ ].

**22.** Pressure inside chamber Ⓗ = [ ] pa

## Piston Ⓓ Turns Pressure into Force

**23.** The fluid pressure applied to piston Ⓓ = [ ] pa

**24.** Complete the formula to find the force of piston Ⓓ:




Pressure ↓ Area ↓

Force = [ ] pa • $2cm^2$

Force of Piston = [ ] newtons

## Master & Slave Cylinders

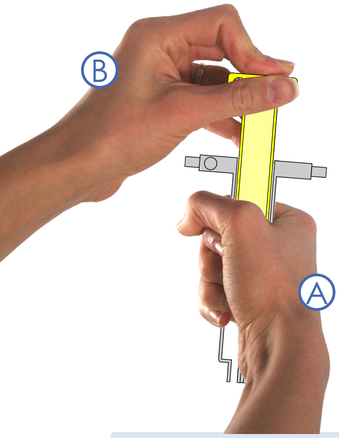
**25.** The cylinders above can be referred to as a **master cylinder** and **slave cylinder**. Why do you think cylinder Ⓑ is referred to as the slave cylinder?

______________________________________________

______________________________________________

## FRICTION

**Friction** is a force that opposes the motion of an object, when the object is in contact with another object or surface. It turns some of the object's kinetic energy into **heat**.




Ⓐ Grip the cylinder.

Ⓑ Push and pull the piston 30 times, as fast as you can.

**26.** What happens to the cylinder as you move the piston? Why does this happen?

________________________________________

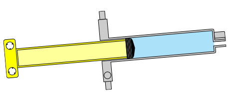
________________________________________

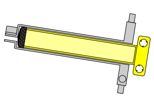
When liquid flows in a hydraulic circuit, friction produces heat (*wasted energy*).

### How can you reduce friction in your hydraulic system?

Shorten the lines
Reduce bends in the line
Properly size the line

**27.** Draw a line that would highly resist the flow of fluid between cylinders:





## VISCOSITY

**Viscosity**: a measure of a fluid's resistance to being deformed. Viscosity is a fluid's resistance to flowing. It can also be called its thickness.

water is *thin*
has **low viscosity**

ketchup is *thick*
has **high viscosity**

**28.** Write the following words in the boxes below in order of least viscous to most viscous: **Milk, Honey, Air, Peanut Butter**

Least Viscous | | | | | Most Viscous

## NON-NEWTONIAN FLUIDS

Fluids without a constant viscosity are called "**Non-Newtonian**" fluids. You can experience a Non-Newtonian fluid, here's how:

Mix two cups cornstarch with one cup water.

+

=

*A fluid that changes viscosity depending on the pressure applied to it.*

### BONUS POINTS

Find a new use (good use) for a **Non-Newtonian** fluid. Present it to your class.

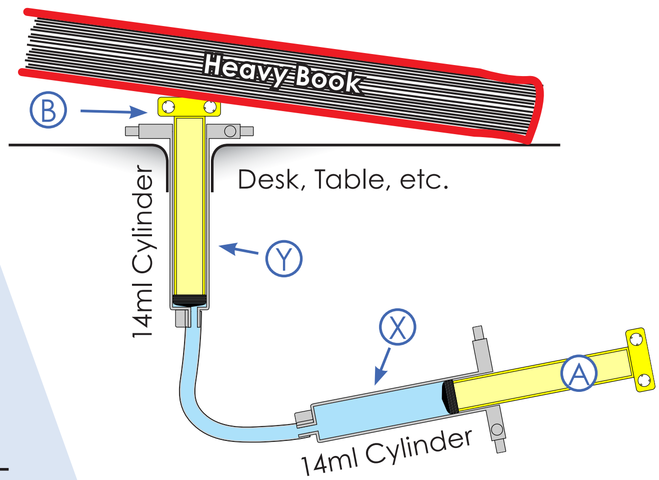
points: ________

## HYDRAULICS

Now we will use a **liquid** to transmit power between cylinders. For the remainder of the lab, you will need 14ml-14ml and 4.5ml-14ml hydraulic systems. Refer to the end of the lab for help.

### Hydraulic Book Work

Create the mechanism shown.
Pushing piston Ⓐ should lift the book.




**29.** Show your teacher the completed mechanism. Explain how it changes force to pressure, transfers the pressure, and then changes it back to force.

Teacher Signature

______________________________

**30.** *Push in* piston Ⓐ 5cm, piston Ⓑ moves [ ] cm out of cylinder Ⓨ.

**31.** *Pull back* piston Ⓐ 5cm, piston Ⓑ moves [ ] cm into cylinder Ⓨ .

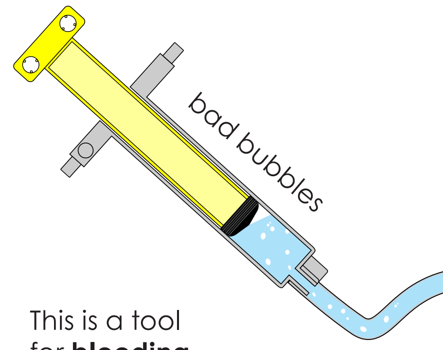
**32.** Pneumatic fluid is highly **compressible**. How compressible is hydraulic fluid?

______________________________

**33.** When you push piston Ⓐ, piston Ⓑ moves immediately. How is that different than the pneumatic system you previously used?

______________________________

## Bubbles are Bad




**34.** Why is it bad to have air bubbles in a hydraulic system?

- [ ] **A** Air bubbles will not compress, but hydraulic fluid will.
- [ ] **B** The air in the system will expand or contract, causing the system to become delayed and transfer less pressure.
- [ ] **C** You can giggle and say that it "*has gas*".


This is a tool for **bleeding** (*removing the air from*) brake lines on cars.

# WORK

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

**Work = Force • Distance**

The **force** is the pull or the push on an object, resulting in its movement.

The **distance** over which the output force is applied.


Forklifts use hydraulics to perform work (moving loads).

## Work on Work

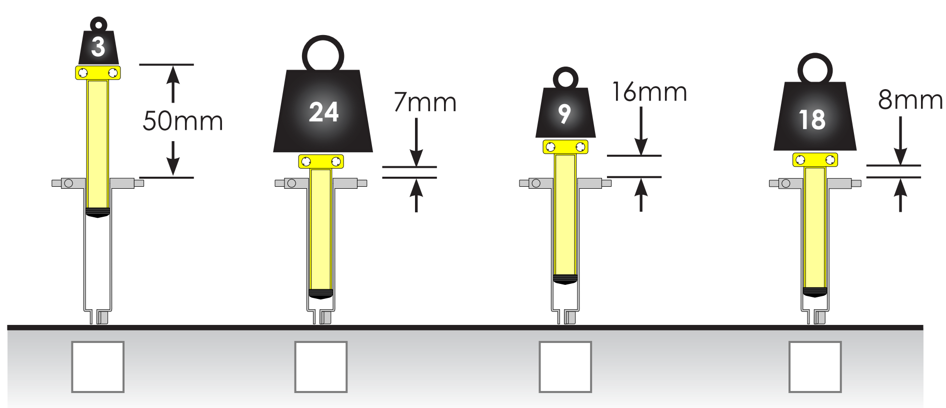
**35.** If schools used the scientific definition for **work**, what would home<u>work</u> be?

______________________________________________

______________________________________________

**36.** The diagram on the right shows cylinders that have lifted weights.

Place an ✔ under the cylinder that has done the most work.



## MECHANICAL ADVANTAGE

**Mechanical Advantage** is the relationship between the work going into a system, and work coming out of a system.

A nutcracker allows you to apply a force larger than you could with your bare hand.

### IMA vs. AMA

Some energy will be lost by a machine (mostly through **friction**).

**Ideal Mechanical Advantage (IMA)** *does not account* for any energy lost.

**$Work_{in}$ = $Work_{out}$ with IMA**

**Actual Mechanical Advantage (AMA)** *accounts* for energy lost.

**$Work_{out}$ < $Work_{in}$ with AMA**

**smaller force** applied over a **larger distance**:

$Force_{in} \cdot Distance_{in}$

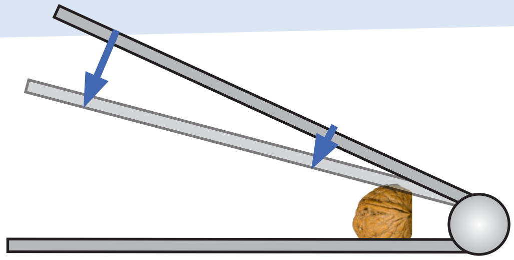
*10n • 1m = 10 pascals*

=

**larger force** applied over a **smaller distance**:

$Force_{out} \cdot Distance_{out}$

*40n • .25m = 10 pascals*



Nutcracker Cracking a Nut

## Ideal Mechanical Advantage

**Work = Force • Distance**

$Work_{in} = Work_{out}$

**$Force_{in} \cdot Distance_{in} = Force_{out} \cdot Distance_{out}$**

- $Force_{in}$: Input Force "*Effort*"
- $Distance_{in}$: The distance over which the input force is applied
- $Force_{out}$: Output Force "*Load*"
- $Distance_{out}$: The distance over which the output force is applied

**$Work_{out}$**
This large cylinder moves a small distance with great force.

**$Work_{in}$**
This small cylinder is repeatedly moved up and down (a large distance) with little force.

**37.** Calculate the **output force**:

$Force_{in} \cdot Distance_{in} = Force_{out} \cdot Distance_{out}$

250n 25m [ ] 10m

## Ideal Mechanical Advantage

Divide the **Distance$_{in}$** by the **Distance$_{out}$** or the **Force$_{out}$** by the **Force$_{in}$** to find the mechanical advantage.

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

can be rearranged as

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


$$\frac{6cm}{0.02cm} = 300$$

The ideal mechanical advantage of the jack can be represented as:

**"300" or "300:1" or "300 to 1"**

**38.** Calculate the Force$_{out}$: Show your work.

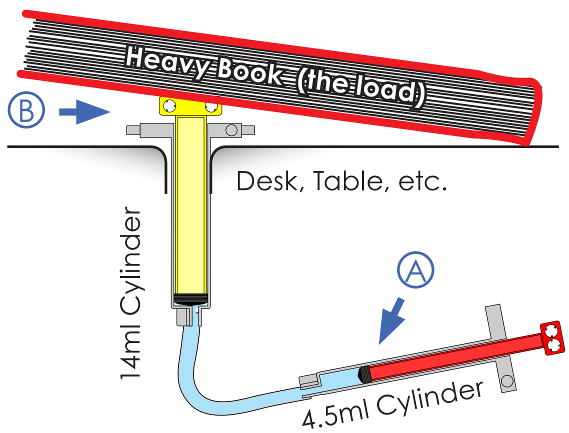
Force$_{in}$ = 23 n

Ideal Mechanical Advantage = 55

Force$_{out}$ = ______

## Distance for Force

Set up the 4.5ml-14ml hydraulic system, as shown, so it will lift a book. Experiment with it and answer the questions below.




**39.** If piston Ⓐ moves 1 cm, piston Ⓑ moves: ______

**40.** Complete the following formula to find the force at piston Ⓑ (**Force$_{out}$**).

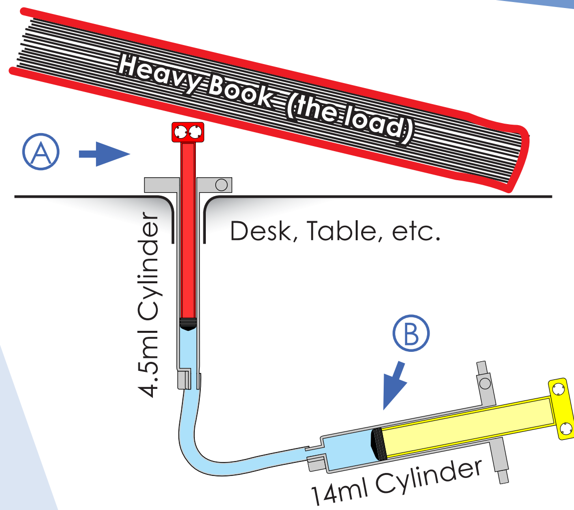
$$\textbf{Ideal Mechanical Advantage} \rightarrow \frac{\textbf{Distance}_{in}}{\textbf{Distance}_{out}} = \frac{\textbf{Force}_{out}}{\textbf{Force}_{in}} \rightarrow \frac{\textbf{1cm}}{\square} = \frac{\square}{\textbf{6 n}}$$

Calculate the Force$_{out}$ by cross multiplying.

**41.** Mechanical Advantage = ______

## Force the Distance

Set up the 4.5ml-14ml hydraulic system, as shown, so it will lift a book. Experiment with it and answer the questions below.




**42.** If piston Ⓑ moves 1 cm, piston Ⓐ moves: ______

**43.** Complete the following formula to find the force at piston Ⓐ (**Force$_{out}$**).

**Ideal Mechanical Advantage** → $\frac{\text{Distance}_{in}}{\text{Distance}_{out}} = \frac{\text{Force}_{out}}{\text{Force}_{in}}$ → $\frac{1\text{cm}}{\_\_\_\_} = \frac{\_\_\_\_}{6\text{n}}$

Calculate the Force$_{out}$ by cross multiplying.

**44.** Mechanical Advantage = ______

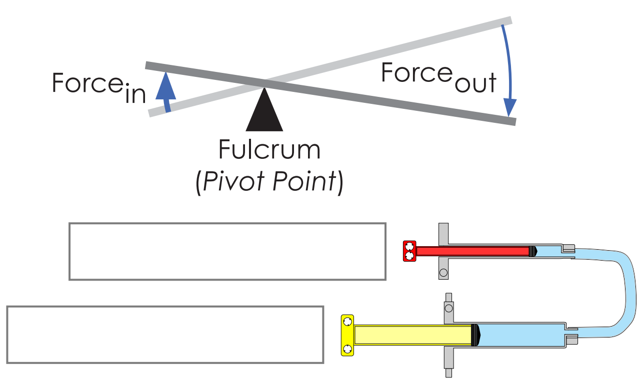
Calculate by dividing the Force$_{out}$ by the Force$_{in}$ or the Distance$_{in}$ by the Distance$_{out}$

HINT: This number should be less than one because this system **loses** force to **gain** distance.

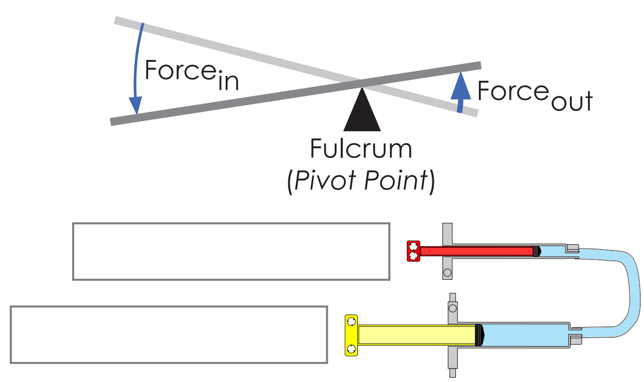
# HYDRAULIC CYLINDERS = A LEVER

Two connected hydraulic cylinders act like a lever, changing the **force**, **distance**, and direction of **movement**.

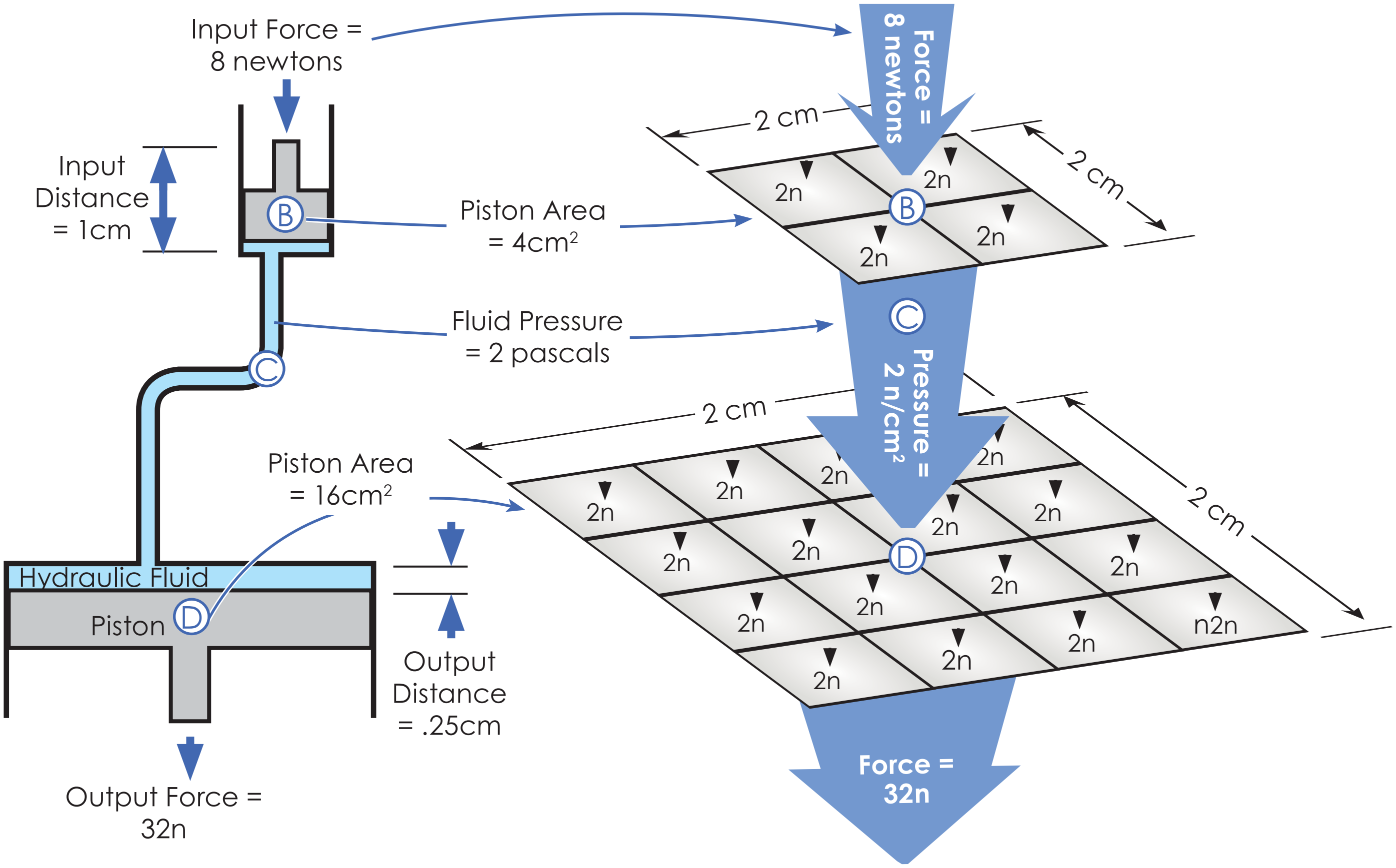
**45.** Label the **Force$_{in}$** and the **Force$_{out}$** on the cylinders below to show a mechanical advantage similar to the lever.




**46.** Label the **Force$_{in}$** and the **Force$_{out}$** on the cylinders below to show a mechanical advantage similar to the lever.



# HOW DOES MECHANICAL ADVANTAGE DEVELOP?




1. 8n of force is applied to piston Ⓑ.

2. The 8n of force is divided over the area of piston Ⓑ and transferred to the fluid (Ⓒ):

$$\frac{\text{Force}}{\text{Piston's Area}} \quad \frac{8n}{4cm^2} = 2n/cm^2 = 2 \text{ pascals}$$

**Fluid Pressure** (2 pascals)

3. Pressure is transferred through fluid Ⓒ (*Pascal's Law*) to piston Ⓓ.

4. Fluid Ⓒ presses against every square inch of piston Ⓓ, creating 32n of force:

**Fluid Pressure** · **Area of Piston** Ⓓ = **Output Force**

$$2n/cm^2 \cdot 16cm^2 = 32n$$

**NOTE:** The /cm² and cm² cancel each other out.

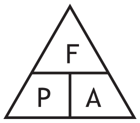
5. Piston Ⓓ applies a downward force of 32n.

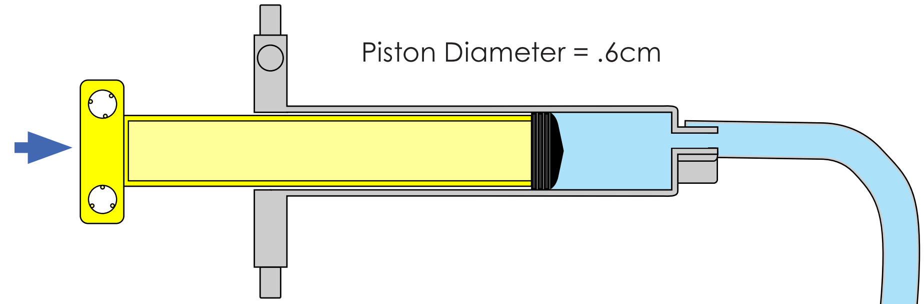
## YOU'RE ON YOUR OWN

**TOTAL POINTS: /10**

A. Find the **Force**$_{out}$, **Distance**$_{out}$ and **mechanical advantage** of the hydraulic system below. Show all work.

Pressure developed from **force** applied over piston area:

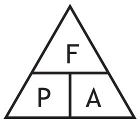



Piston force developed from **fluid pressure** over piston area:

Force$_{out}$ =

Piston Diameter = .3cm




Distance$_{out}$ =

Mechanical Advantage =

# A FLUID POWERED INVENTION

B. Design and draw an invention that uses **hydraulic**s or **pneumatics** to perform one of the following tasks: open a jar, crack an egg, or toss a ball.

| | | |
|---|---|---|
| Presentation | Is it well drawn and easy to understand? | /3 |
| Function | Could it really work? Does it use fluid power? | /3 |
| Creativity | Does it solve the task in a new and different way? | /4 |
| | total points: | /10 |

## CONGRATULATIONS!!

You've finished the Fluid Power Lab.
It's time to create a fluid powered contraption.

# FLUID POWER LAB

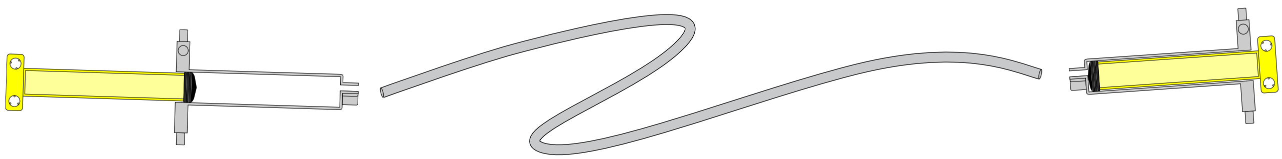
## ASSEMBLY REFERENCE SHEET

Use the tubing lengths specified for your hydraulic activity (shown on page 2).

### Pneumatics

1 Have one cylinder all the way open.

2 One cylinder all the way closed.



3 Connect cylinders with tubing.
*(use length shown on page 2).*

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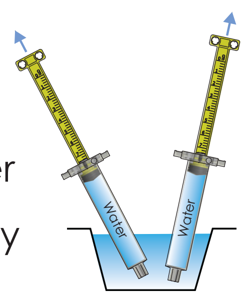
### Hydraulics

1 Fill both cylinders with water:

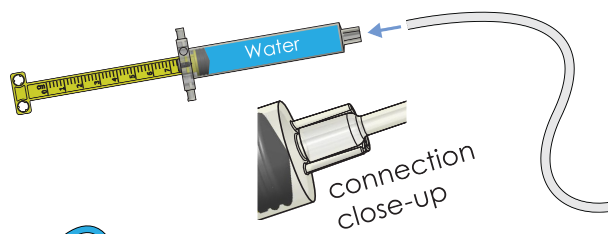
Ⓐ Push cylinder piston in

Ⓑ Place cylinder tip underwater

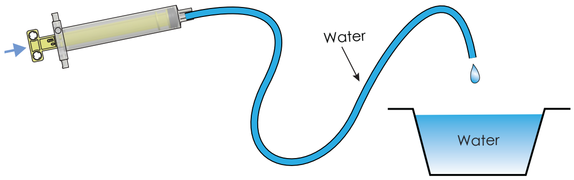
Ⓒ Pull piston back to completely fill the cylinder with water



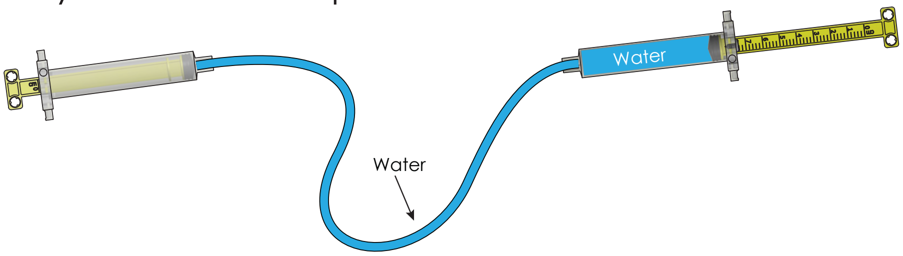

2 Attach tubing (as noted for activity) to filled cylinder.




3 Fill the tubing completely with water by pushing the piston completely in.




4 Attach the water-filled tubing to the remaining water-filled cylinder from Step 1.




5 Insert a cylinder screw as shown to prevent the tubing from pulling off.