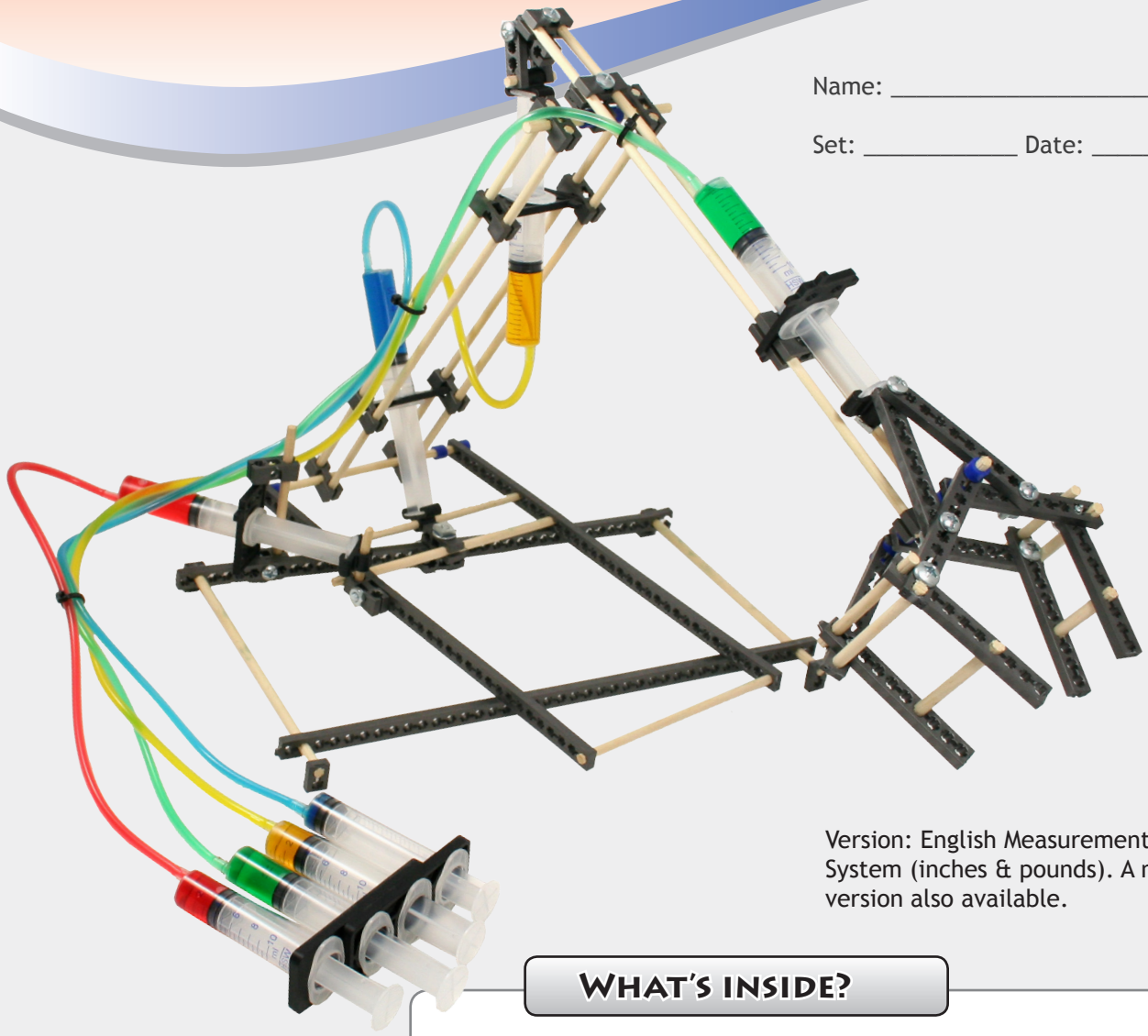
Revision 4.2

Fluid Power Lab



Name: _____

Set: _____ Date: _____

Version: English Measurement System (inches & pounds). A metric version also available.

What's Inside?

This lab will provide you with experiences in and an understanding of:

- Hydraulic Systems
- Pneumatic Systems
- Cylinders
- Pascals Law
- Liquids and Gasses
- Pressure
- Kinetic and Potential Energy
- Mechanical Advantage
- Friction
- Viscosity
- Work

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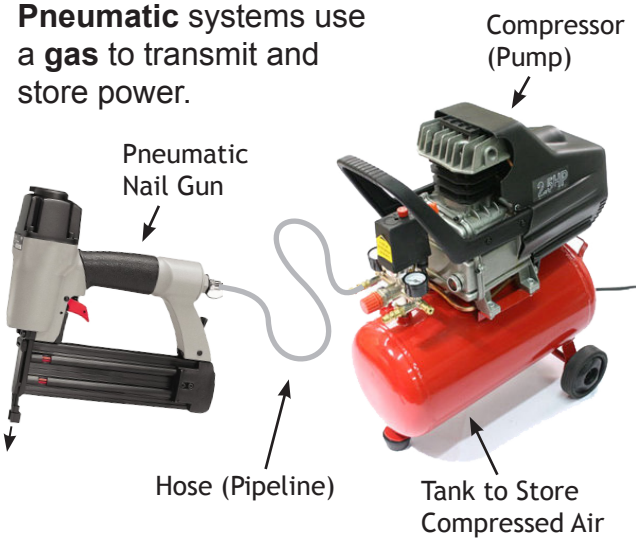
Fluid Power

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.

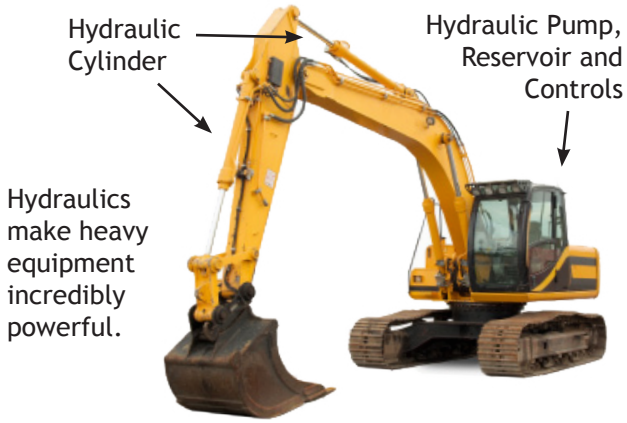
Pneumatics

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



Hydraulics

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



Pneumatic Devices

1. List 2 devices, other than the ones shown above, that use pneumatics for operation.

_____

_____

Hydraulic Devices

2. List 2 devices, other than the ones shown above, that use hydraulics for operation.

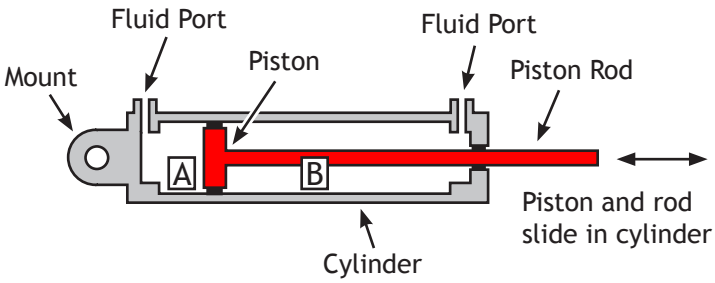
_____

_____

Cylinders

Cylinders transform pressure and fluid flow into mechanical force.

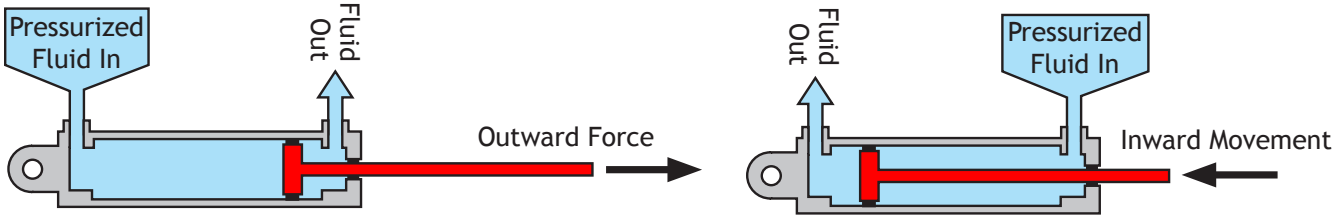
Anatomy of a Cylinder



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

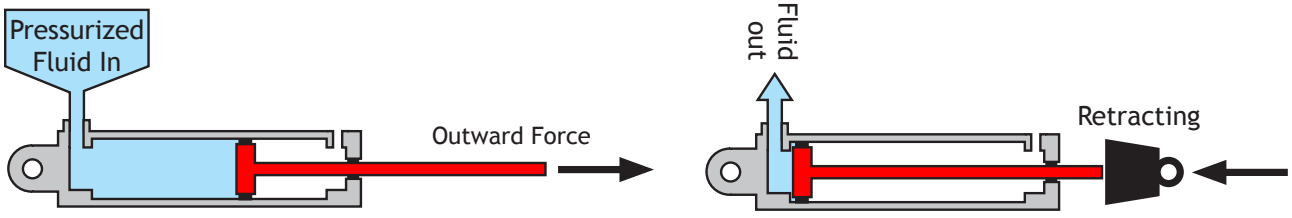
Double-Acting Cylinders

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.

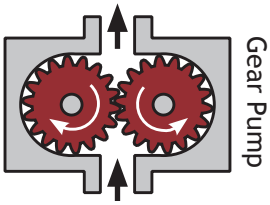


Double-Acting Cylinders

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



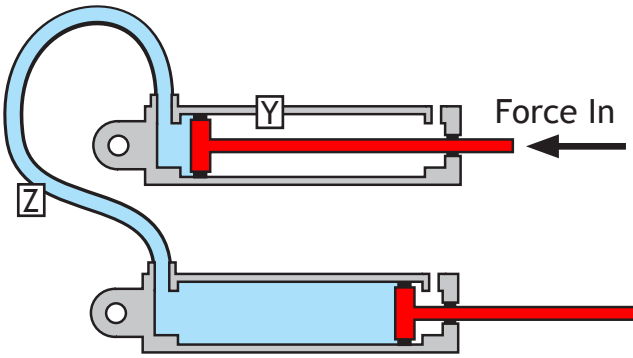
Pumps that power cylinders usually only create a positive fluid pressure (push fluid). That is why most cylinders, like the ones shown above, are designed to only be powered by positive fluid pressure.



Your Cylinders will Pull & Push

You will use a cylinder as a pump. The cylinder will be able to push fluid (creating a postive 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:



3. There is a ☐ Positive ☐ Negative pressure in line Z.

4. Cylinder Y is ☐ pulling ☐ pushing fluid.

Syringes as Cylinders

You will be turning syringes (not the ones with needles) into pneumatic and hydraulic cylinders.

Match the components with their name by placing letters into the boxes below:

5. Piston: ☐

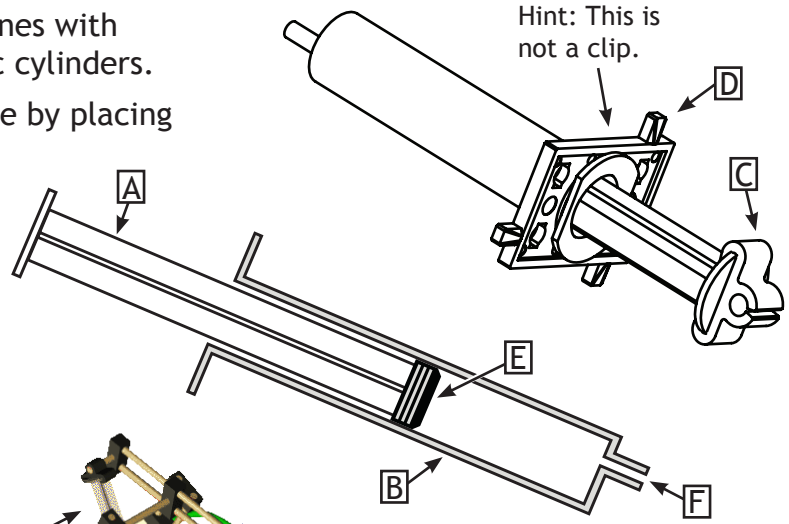
6. Piston Rod: ☐

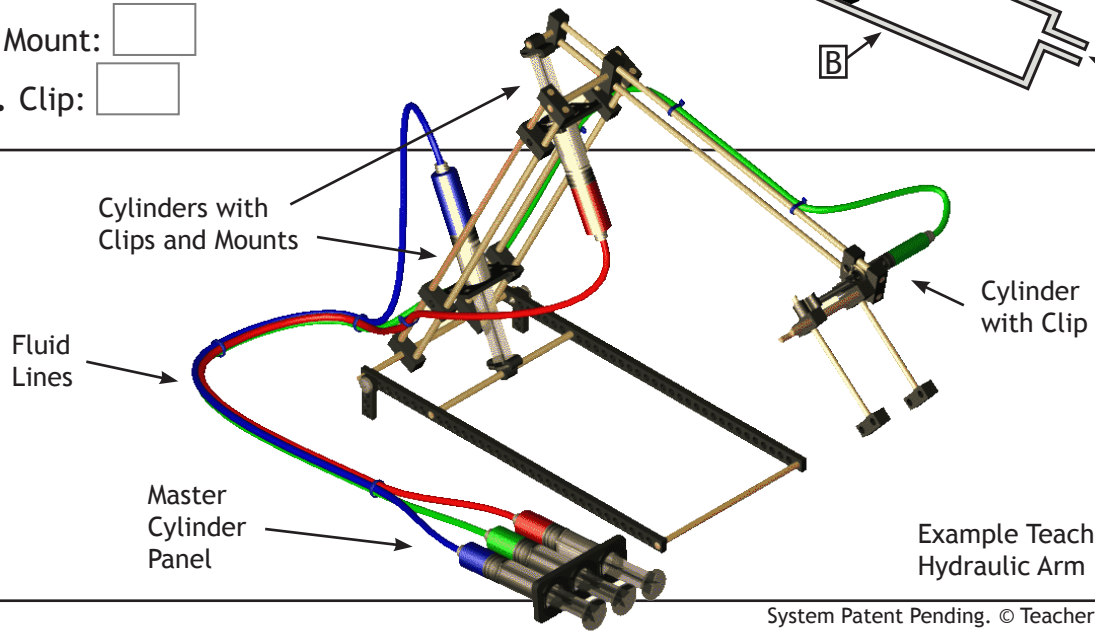
7. Cylinder: ☐

8. Fluid Port: ☐

9. Mount: ☐

10. Clip: ☐





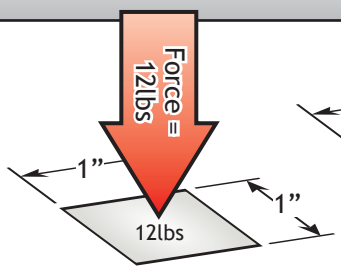
Example TeacherGeek Hydraulic Arm

WHAT IS PRESSURE?

Pressure is a **force** applied over an **area**:

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

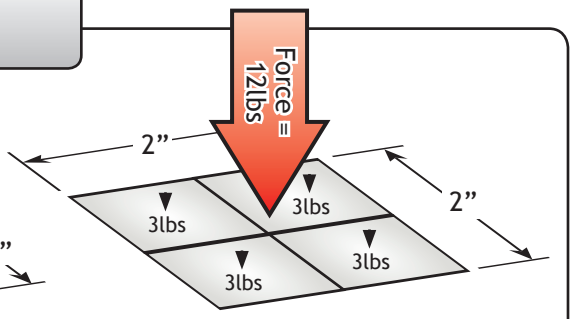
The area over which the force is applied.



$1in \bullet 1in = 1in^2$

$\frac{12lbs}{1in^2} = 12lbs/in^2$

Less Area = More Pressure

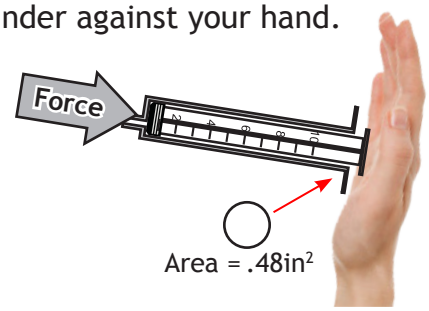


$2in \bullet 2in = 4in^2$

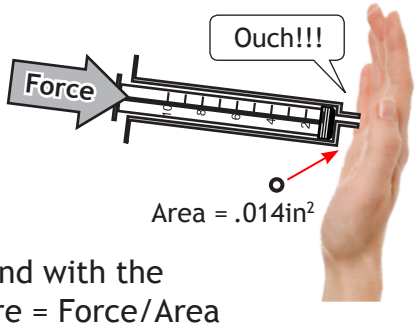
$\frac{12lbs}{4in^2} = 3lbs/in^2$

More Area = Less Pressure

Step 1: Push the piston end of a 10ml cylinder against your hand.



Step 2: Use the same amount of force as you did for step 1 to push the fluid port end of the 10ml cylinder against your hand.



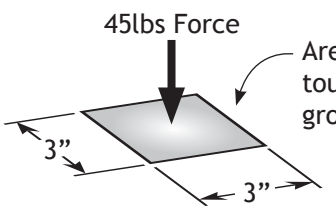
11. Both ends of the cylinder were pushed against your hand with the same force. Explain why they felt different? Hint: Pressure = Force/Area

_____

_____

PUTTING YOUR FOOT DOWN

A foot pushes down on a $3in^3$ cube with 24lbs of force.



12. How much pressure does the cube apply to the ground?

Show your work:

Answer: _____

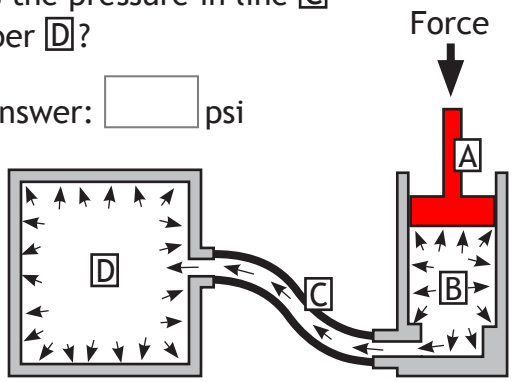
PASCAL'S LAW

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

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

If the pressure is 5psi in chamber [B], what is the pressure in line [C] and chamber [D]?

13. Answer: _____ psi



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

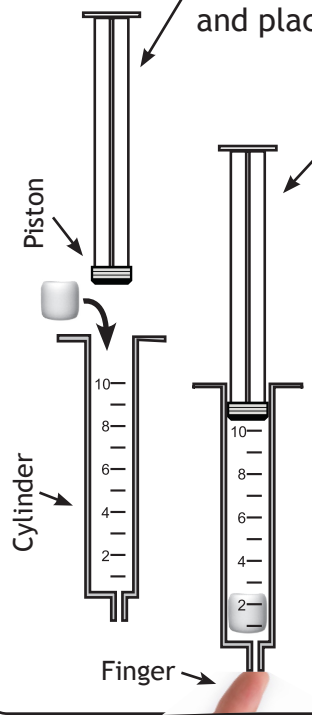
Squeezing a toothpaste tube creates an external pressure applied to the toothpaste inside. The toothpaste transmits the force equally in all directions; pushing the toothpaste out of the tube and making the tube walls bulge.

1 cubic centimeter (cc)
=
1ml (1 milliliter)

Something you never wanted to know...

3785.4ml= 1 gallon

PRESSURIZING MARSHMALLOWS



1st Pull the piston out from a 10cc cylinder (syringe) and place one small marshmallow inside the chamber.

2nd Push the piston in while covering the fluid port with your finger. Watch what happens to the marshmallow.

3rd Push the piston in with your finger off the port.

4rd Put your finger over the port and pull the piston back. Watch the Marshmallow.

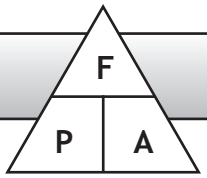
14. Why, according to Pascal's Law, did the marshmallow change?

_____

_____

_____

FIND THE UNKNOWN



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

Lets look at another way to write the formula:
Pressure = Force/Area

Pressure = $\frac{\textbf{Force}}{\textbf{Area}}$ can be written as:

P = Pressure
F = Force
A = Area

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

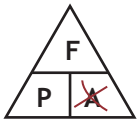
You know: Pressure, Area
You need to find: Force

Force = Pressure • Area

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

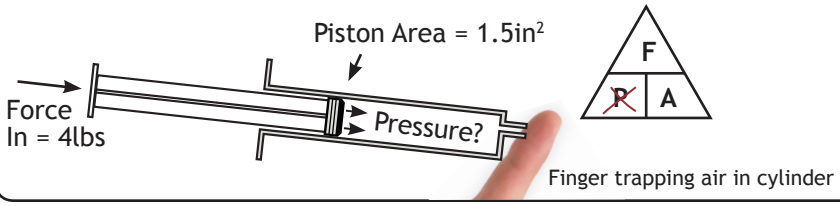
Pressure = Force/Area

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



Area = Force / Pressure

15. Pressure transfers between the piston and fluid in the cylinder. Calculate the pressure developed when a force of 4lbs is applied to the piston. Show your work.

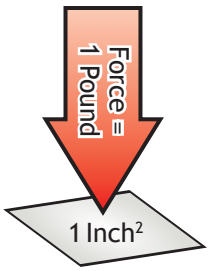


Answer: _____ psi

MEASUREMENTS OF PRESSURE

LBS/IN² (PSI)

A force of 1 pound applied over an area of 1 square inch produces a pressure of 1 pounds per square inch.

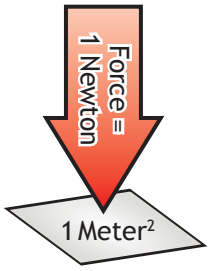


= 1 psi

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.



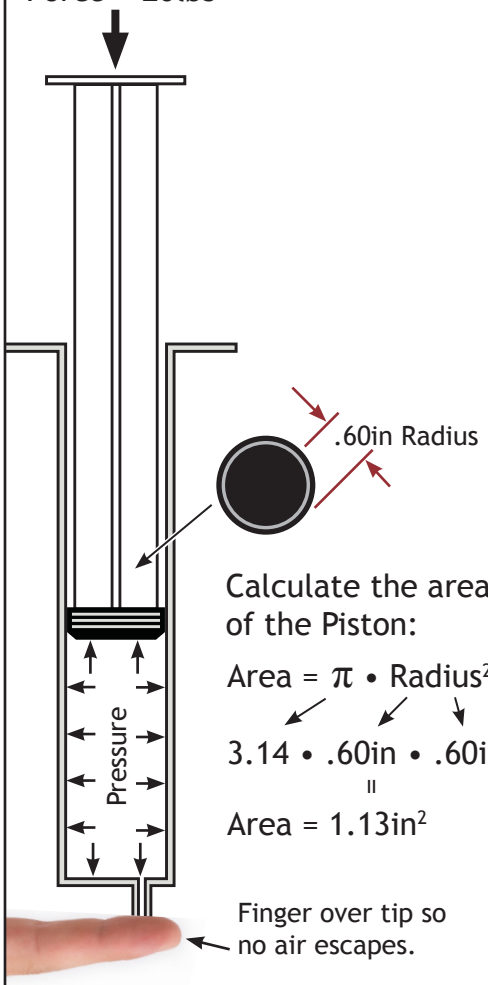
= 1 Pa

Pascal can be abbreviated as "Pa"

CALCULATING PRESSURE

EXAMPLE CALCULATION

Force = 20lbs



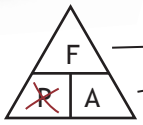
Calculate the area of the Piston:

Area = π • Radius^2

3.14 • .60in • .60in

=

Area = 1.13in^2



$\frac{20\text{lbs}}{1.13\text{in}^2}$ = 17.7lbs/in^2

Answer:

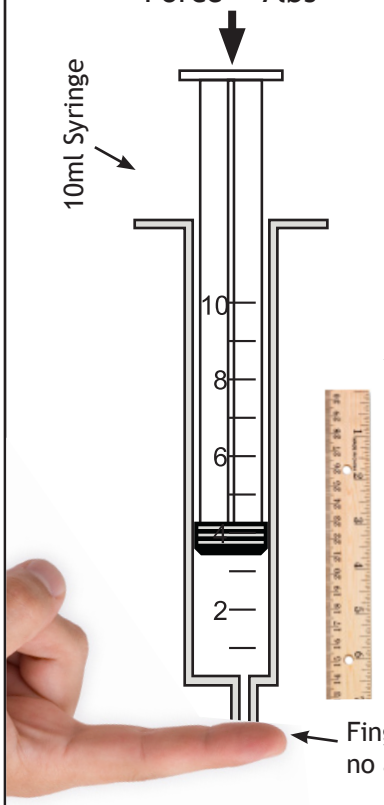
The Air Pressure inside the syringe chamber = 17.7psi

Most pneumatic nail guns use 50-100psi

YOUR CALCULATION

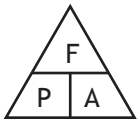
16. Calculate the pressure inside the syringe.

Force = 7lbs



Formulas:

Area of a circle = π • Radius^2



P = Pressure
F = Force
A = Area

Note: Measure a real 10ml syringe to find the area of its piston (not the drawing on this paper).

Show your calculations below:

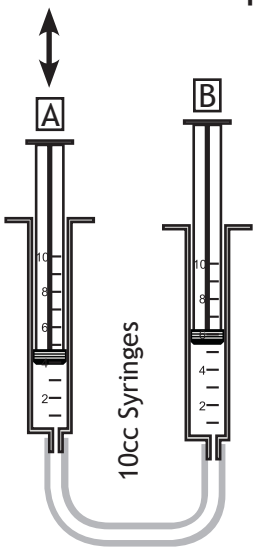
Answer: _____

Pneumatic Play

See how a gas can transfer fluid and pressure between cylinders. You will need a 10ml to 10ml pneumatic system for this section.

Push One Piston

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



Complete the following sentences using some of these words: faster,

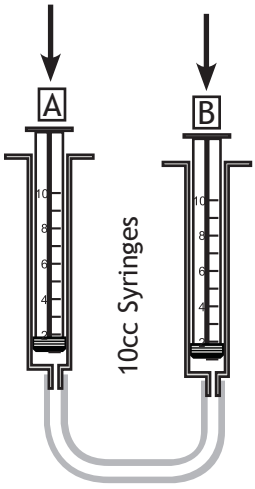
17. The pistons move _____ to each other.

18. Piston B moves _____ than piston A (the piston you pushed and pulled) due to air compressing and expanding.

19. The pressure applied by piston A _____ though the _____ (air) to piston B, applying a _____ that causes the piston B to move.

Push Both Pistons

Push both pistons in. Examine what happens and answer the questions below.



Complete the following sentences using some these words:
goat, force, psi, potential, compresses, kinetic

20. An external _____ is needed to move the pistons into the cylinders.

21. The pressure applied by the pistons _____ the air in the cylinders and line.

22. _____ means the same thing as lbs/in^2.

23. Compressed air has _____ (stored) energy.

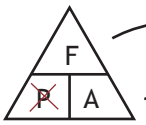
24. After pushing both pistons in, quickly let go of one piston. The piston you let go of moves outward with _____ energy.

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.

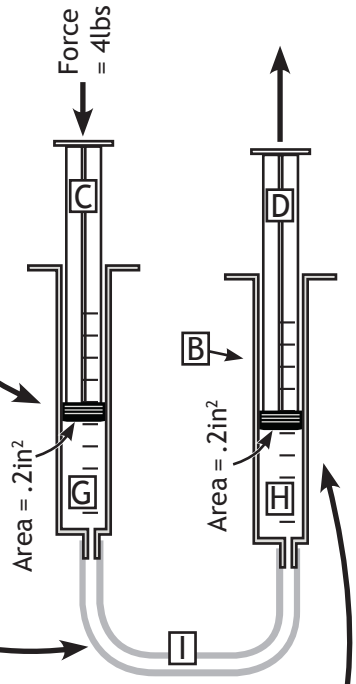
Piston C Applies Pressure

25. Complete the formula used to find the pressure applied by piston C:



$\frac{\square}{2in^2}$ = Pressure

26. Pressure inside Chamber G = _____ psi



Fluid Transfers The Pressure

27. pressure is transmitted from chamber G through line ____ to chamber ____.

28. The pressure inside chamber H = _____ psi

Piston D Turns Pressure Into Force

29. The fluid pressure applied to piston D = _____ psi

30. Complete the equation and find force the force of piston D:

We know pressure and area, but need to find force.

Pressure ↓ Area ↓

Force = _____ psi • $2in^2$

Force of Piston D = _____ lbs

Master & Slave Cylinders

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

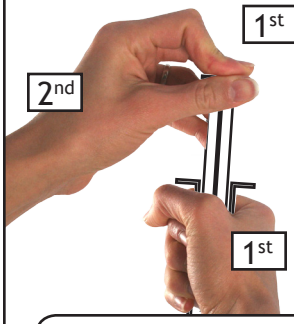
_____

_____

Think!

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.



1st Grip the cylinder. 2nd Push and pull the piston 30 times, as fast as you can.

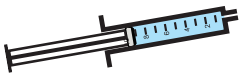
32. What happens to the cylinder as you move the piston? Why does this happen?

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

33. 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 fluid's resistance to flowing. It can also be called its thickness.

Water is "thin" and has a low viscosity

Ketchup is "thick" and has a higher viscosity.

34. Write the following words in the boxes below so they are arranged from least viscous to most viscous: Milk, Honey, air, Peanut Butter

Least Viscous → Most Viscous

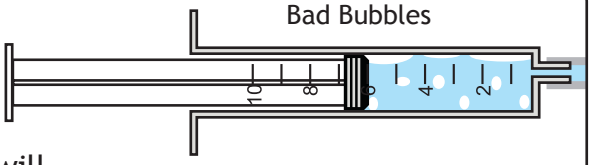
Hydraulics

Now we will use a **liquid** to transmit power between cylinders. You will need a 10ml to10ml and 3ml to10ml hydraulic system for this section.

Bubbles Are Bad

35. 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.
- ☐ D. You can giggle and say that it "has gas."

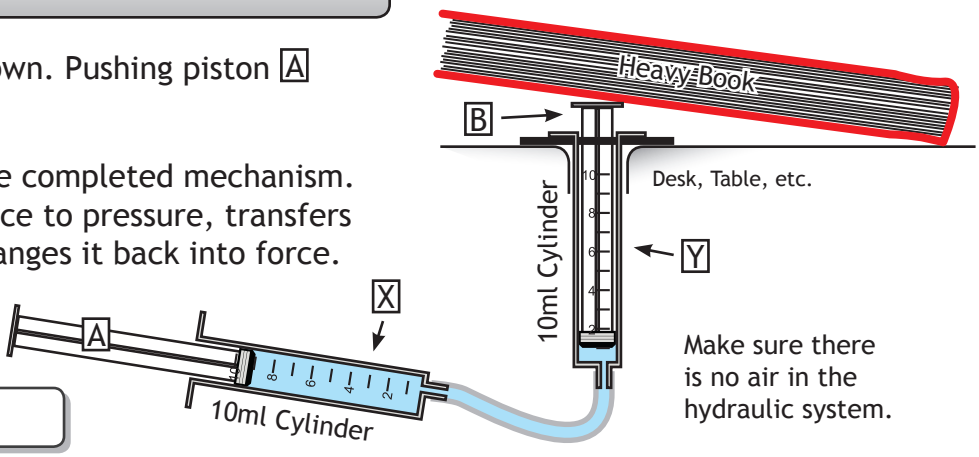


This is a tool for bleeding (removing the air from) brake lines on cars.

Hydraulic Book Work

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

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



Make sure there is no air in the hydraulic system.

Teacher Signature:

37. ***Push in*** piston [A] 1 inch , piston [B] moves _____ out of cylinder [Y].

38. ***Pull back*** piston [A] 1 inch, piston [B] moves _____ into cylinder [Y].

39. Pneumatic fluid is highly compressible. How compressible is hydraulic fluid?

_____

40. When you push piston [A], piston [B] moves immediately. How is this different than the pneumatic system you previously used?

_____

NON-NEWTONIAN FLUIDS

Fluids without a constant viscosity are called Non-Newtonian fluids. You can experience a Non-Newtonian fluid...

Mix 2 cups of cornstarch with 1 cup water.

+

=

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

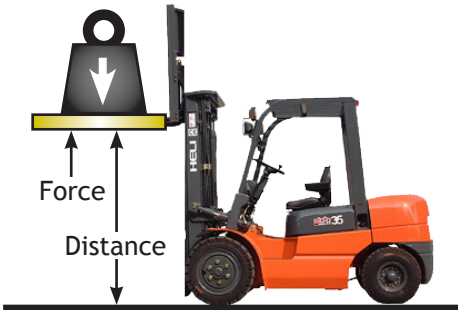
WORK

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

Work = Force • Distance

Force: 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).

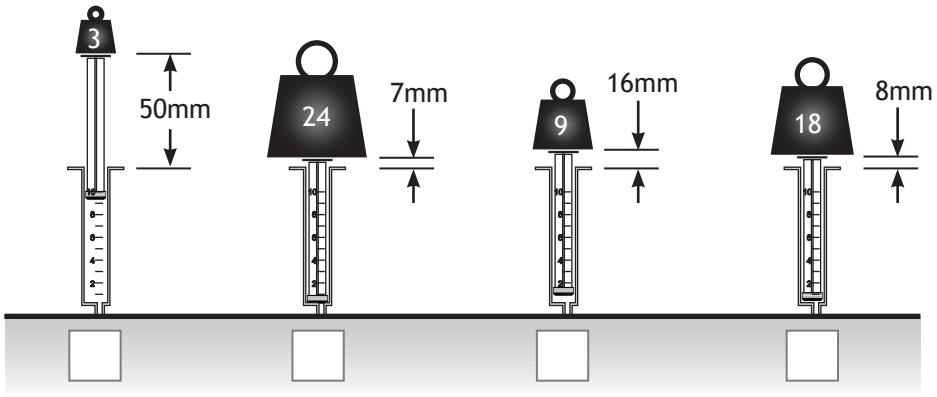
WORK ON WORK

41. If schools used the scientific definition for work, how could homework be different?

_____

_____

42. The following diagram shows cylinders that have lifted weights. Place an "X" under the cylinder that has done the most work?



MECHANICAL ADVANTAGE

Mechanical Advantage is the relationship between the work going in to 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.

Force can be traded for distance, or distance can be traded for force.

WORK IN

A smaller force is applied over a larger distance:

$Force_{in} \bullet Distance_{in}$

10lbs • 1in

=

10in-lbs

=

WORK OUT

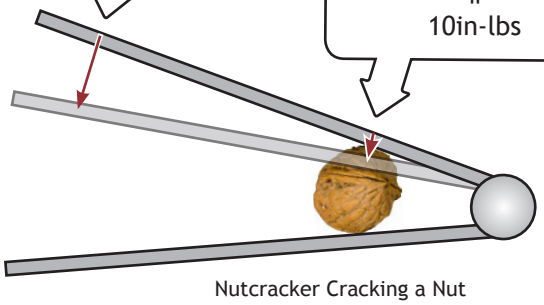
A larger force is applied over a smaller distance:

$Force_{out} \bullet Distance_{out}$

40lbs • .25in

=

10in-lbs



Nutcracker Cracking a Nut

IMA vs. AMA

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

Ideal Mechanical Advange (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

IDEAL MECHANICAL ADVANTAGE

Work = Force • Distance

so...

$Work_{in} = Work_{out}$

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

Input Force
Also called "Effort"

The distance over which the input force is applied

Output Force
Also called "Load"

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.

43. Calculate the **output force:**

$Force_{in}$	•	$Distance_{in}$	=	$Force_{out}$	•	$Distance_{out}$
250lbs		25in				10in

IDEAL MECHANICAL ADVANTAGE (CONTINUED)

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

↑ can be rearranged" as ↓

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

Divide the Distance_{in} by the Distance_{out} or the Force_{out} by the Force_{in} to find the mechanical advantage.

44. Calculate the Force_{out}:

Ideal Mechanical Advantage= 55 Force_{in}= 23lbs

$$\frac{55}{1} = \frac{\square}{23\text{lbs}} \quad \text{Force}_{out} \text{ in } \text{Force}_{in}$$

Cross multiply to solve.

Calculating mechanical advantage:

Distance_{out} = .02in

Distance_{in} = 6in

Bottle Jack

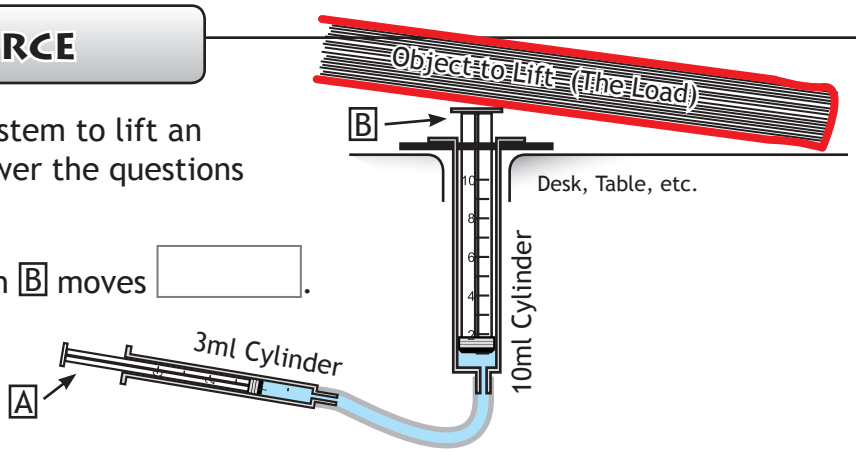
$$\frac{6\text{in}}{.02\text{in}} = 300$$

This means that the input force will be

"300" or "300/1" or "300 to 1"

DISTANCE FOR FORCE

Set up the 3ml to 10ml hydraulic system to lift an object. Experiment with it and answer the questions below.



45. If piston A moves 1 inch, piston B moves ____.

46. Complete the following formula to find the distance traveled and force at piston B

Calculate the force_{out} by cross multiplying.

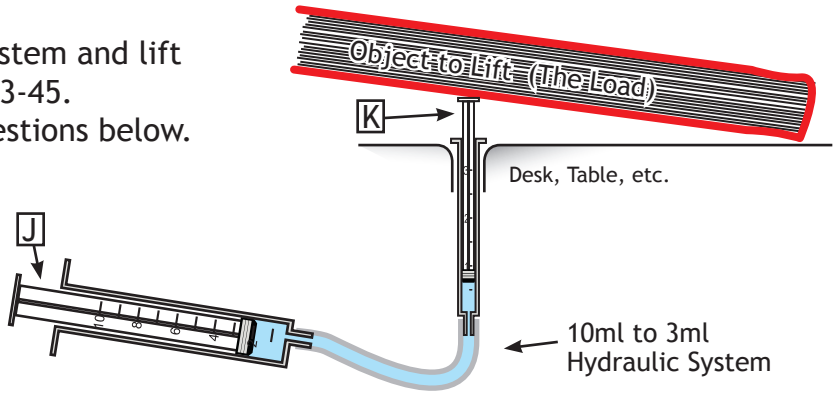
Ideal Mechanical Advantage → $\frac{\text{Distance}_{in}}{\text{Distance}_{out}} = \frac{\text{Force}_{out}}{\text{Force}_{in}}$ → $\frac{1in}{\square} = \frac{\square}{6lbs}$

47. Mechanical Advantage = ____.

Calculate by dividing the Force_{out} by the Force_{in} or the Distance_{in} by the Distance_{out}.

FORCE FOR DISTANCE

Reverse the 3ml to 10ml hydraulic system and lift the same object used for questions 43-45. Experiment with it to answer the questions below.



48. If piston [J] moves .5inches, piston [K] moves _____.

49. Complete the following formula to find the distance traveled and force at piston [B]

Calculate the $force_{out}$ by cross multiplying.

Ideal Mechanical Advantage → $\frac{Distance_{in}}{Distance_{out}} = \frac{Force_{out}}{Force_{in}}$ → $\frac{.5\ in}{\quad} = \frac{\quad}{6\ lbs}$

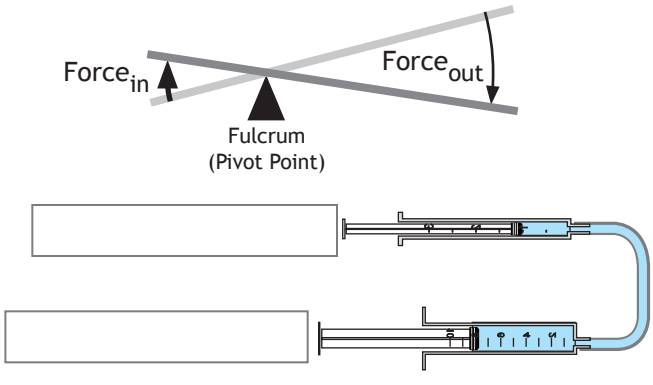
50. Mechanical Advantage = _____ ← Calculate by dividing the $Force_{out}$ by the $Force_{in}$ or the $Distance_{in}$ by the $Distance_{out}$.

Hint: This number should be less than 1 because this system looses force to gain distance

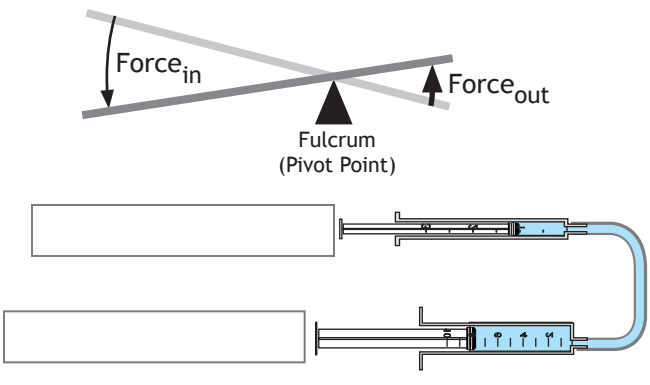
HYDRAULIC CYLINDERS = LEVER

When cylinders with pistons of different sizes are connected, they can act like a lever, changing the force, distance and direction movement.

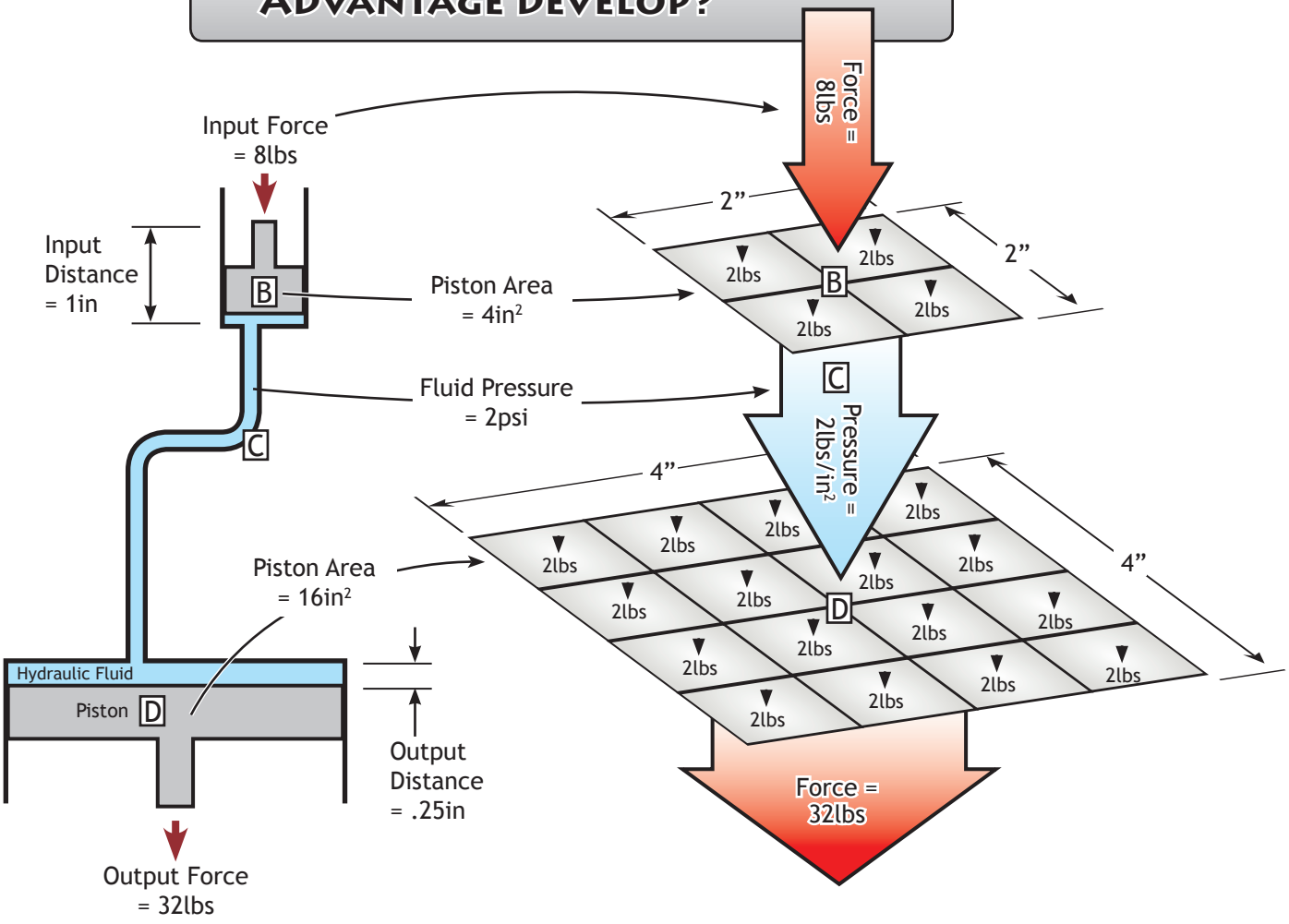
51. Label the $Force_{in}$ and $Force_{out}$ on the cylinders below to show a mechanical advantage similar to the lever.



52. Label the $Force_{in}$ and $Force_{out}$ on the cylinders below to show a mechanical advantage similar to the lever.



How does the Mechanical Advantage develop?



1st 8lbs of force is applied to the piston B.

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

Force → $\frac{8\text{lbs}}{4\text{in}^2} = 2\text{lbs/in}^2$ ← Fluid Pressure

Piston's Area →

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

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

Fluid Pressure → $2\text{lbs/in}^2 \bullet 16\text{in}^2 = 32\text{lbs}$ ← Output Force

Area of Piston D →

← Note: The /in² and in² cancel each other out.

3nd Piston D applies a downward force of 32lbs.

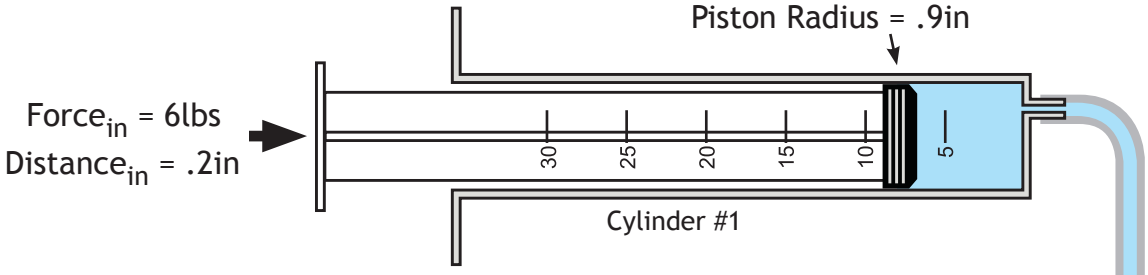
YOU'RE ON YOUR OWN...

Find the $Force_{out}$, $Distance_{out}$ and mechanical advantage of the hydraulic system below. Show all work. Use the concepts and formulas from previous pages.

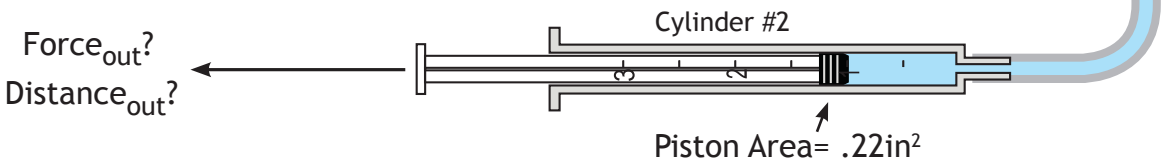
Pressure Developed From Force Applied Over Piston Area:

53. Calculate the cylinder #1 piston area:

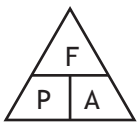
54. Calculate pressure applied to the fluid:



Piston Force Developed From Fluid Pressure Over Piston Area:



55. Find the cylinder #2 force$_{out}$:



56. Calculate the distance$_{out}$:

57. Calculate the Mechanical Advantage: