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

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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.

<table>
<thead>
<tr>
<th>Device</th>
<th>How does it use pneumatics?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hydraulic Devices

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

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</tbody>
</table>
CYLINDERS

Cylinders transform pressure and fluid-flow into mechanical force.

**Anatomy of a Cylinder**

Chambers A and B 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.

Know Your Parts

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

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

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Example TeacherGeek Advanced Hydraulic Arm

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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.

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 3in³ cube with 45lbs 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:

\[
\text{Pressure} = \frac{\text{Force}}{\text{Area}}
\]

This can be written as:

\[
\begin{align*}
P &= F/A \\
P &= \text{Pressure} \\
F &= \text{Force} \\
A &= \text{Area}
\end{align*}
\]

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

<table>
<thead>
<tr>
<th>You know:</th>
<th>You need to find:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, Area</td>
<td>Force</td>
</tr>
<tr>
<td>Force, Area</td>
<td>Pressure</td>
</tr>
<tr>
<td>Pressure, Force</td>
<td>Area</td>
</tr>
</tbody>
</table>

6. Pressure transfers between the piston and the fluid in the cylinder. Calculate the force of the piston when the fluid applies 20lbs/in\(^2\) to it.

**MEASUREMENTS OF PRESSURE**

**Lbs/in\(^2\) (psi)**

A force of 1 pound applied over an area of 1 square inch produces a pressure of 1 pound per square inch (11b/in\(^2\)).

A force of 1 pound 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”

Answer: [Blank] psi
**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.

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

Answer: psi

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**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

1. Calculate the Area of the Piston

   - 0.3in Radius
   - Area = \( \pi \times \text{Radius}^2 \)
   - \( 3.14 \times 0.3in \times 0.3in \)
   - Area = 0.28in\(^2\)

2. Calculate Pressure

   - Force = 20lbs
   - Area = 0.28in\(^2\)
   - \( \frac{20lbs}{0.28in^2} = 71.4\text{lbs/in}^2 \)

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

Your Calculation

10. Calculate the pressure inside the cylinder.

   - Force = 7lbs

Formulas:

- Area of a circle = \( \pi \times \text{Radius}^2 \)
- \( P = \text{Pressure} \)
- \( F = \text{Force} \)
- \( A = \text{Area} \)

**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.

Push One Piston

Push and pull piston A. 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 B moves __________ than piston A (the piston you pushed and pulled) due to air compressing.

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

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

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
- psi
- 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 lbs/in².

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 C:

\[
\frac{F \times A}{2\text{in}^2} = \text{Pressure}
\]

20. Pressure inside chamber C = [ ] psi

Fluid Transfers the Pressure

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

22. Pressure inside chamber H = [ ] psi

Piston D Turns Pressure into Force

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

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

\[
\text{Force} = \frac{F \times A}{2\text{in}^2}
\]

Master & Slave Cylinders

25. 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?
FRICION

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.

A. Grip the cylinder.
B. 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).

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

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

How can you reduce friction in your hydraulic system?

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

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

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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.

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 A 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 A 5cm, piston B moves cm out of cylinder Y.

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

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

33. When you push piston A, piston B moves immediately. How is that different than the pneumatic system you previously used?
Forklifts use hydraulics to perform work (moving loads).

**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".

**WORK**

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

\[ \text{Work} = \text{Force} \times \text{Distance} \]

- The **force** is the pull or the push on an object, resulting in its movement.
- The **distance** over which the output force is applied.

**Work on Work**

35. If schools used the scientific definition for **work**, what would homework be?

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

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

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

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

Work = Force • Distance

Forklifts use hydraulics to perform work (moving loads).
MECHANICAL ADVANTAGE

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

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.

\[ \text{Work}_{\text{in}} = \text{Work}_{\text{out}} \text{ with IMA} \]

Actual Mechanical Advantage (AMA) accounts for energy lost.

\[ \text{Work}_{\text{out}} < \text{Work}_{\text{in}} \text{ with AMA} \]

Ideal Mechanical Advantage

\[ \text{Work} = \text{Force} \times \text{Distance} \]

\[ \text{Work}_{\text{in}} = \text{Work}_{\text{out}} \]

\[ \text{Force}_{\text{in}} \times \text{Distance}_{\text{in}} = \text{Force}_{\text{out}} \times \text{Distance}_{\text{out}} \]

The distance over which the input force is applied

The distance over which the output force is applied

Input Force “Effort”

Output Force “Load”

37. Calculate the output force:

\[ \text{Force}_{\text{in}} \times \text{Distance}_{\text{in}} = \text{Force}_{\text{out}} \times \text{Distance}_{\text{out}} \]

250lbs \hspace{1cm} 25in \hspace{1cm} \underline{\hspace{2cm}} \hspace{1cm} 10in
**Ideal Mechanical Advantage**

Divide the Distance in by the Distance out or the Force out by the Force in to find the mechanical advantage.

\[
\text{Ideal Mechanical Advantage} = \frac{\text{Distance in}}{\text{Distance out}} = \frac{\text{Force out}}{\text{Force in}}
\]

38. Calculate the \( \text{Force out} \): Show your work.
   \[ \text{Force in} = 23 \text{lbs} \]
   Ideal Mechanical Advantage = 55

39. If piston A moves 1 inch, piston B moves: 

40. Complete the following formula to find the force at piston B (\( \text{Force out} \)).

   \[
   \frac{\text{Ideal Mechanical Advantage}}{\text{Distance in}} = \frac{\text{Force out}}{\text{Distance out}}
   \]

   \[ \text{Ideal Mechanical Advantage} = 300 \]

   \[ \text{Distance out} = 0.02 \text{in} \]

   \[ \text{Distance in} = 6 \text{in} \]

   \[ \frac{6 \text{in}}{0.02 \text{in}} = 300 \]

   The ideal mechanical advantage of the jack can be represented as: "300" or "300:1" or "300 to 1"

41. Mechanical Advantage = 

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**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.

**Bottle Jack**

**Heavy Book (the load)**

**4.5ml Cylinder**

**14ml Cylinder**

**Desk, Table, etc.**
**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 B moves 1 inch, piston A moves: ___________

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

\[
\text{Ideal Mechanical Advantage} \Rightarrow \frac{\text{Distance}_{\text{in}}}{\text{Distance}_{\text{out}}} = \frac{\text{Force}_{\text{out}}}{\text{Force}_{\text{in}}} \Rightarrow 1\text{in} = 6\text{lbs}
\]

44. Mechanical Advantage = ___________

**HYDRAULIC CYLINDERS = A LEVER**

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

45. Label the Force\(_{\text{in}}\) and the Force\(_{\text{out}}\) on the cylinders below to show a mechanical advantage similar to the lever.

46. Label the Force\(_{\text{in}}\) and the Force\(_{\text{out}}\) on the cylinders below to show a mechanical advantage similar to the lever.
1. 8lbs of force is applied to piston B.

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

   \[
   \text{Force} \quad \frac{8\text{lbs}}{4\text{in}^2} = 2\text{lbs/in}^2 \\
   \text{Fluid Pressure}
   \]

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

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

   \[
   \text{Fluid Pressure} \quad \text{Area of Piston D} \quad \text{Output Force} \\
   2\text{lbs/in}^2 \times 16\text{in}^2 = 32\text{lbs}
   \]

5. Piston D applies a downward force of 32lbs.
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:

\[ P = \frac{F}{A} \]

Force_in = 6lbs
Distance_in = .3in

Piston force developed from fluid pressure over piston area:

\[ F_{out} = P \times A \]
\[ D_{out} = \frac{F_{out}}{P} \]

Piston Diameter = .6in

\[ F_{out} = \quad \]  
\[ D_{out} = \quad \]

Piston Diameter = .35in

Mechanical Advantage =
A FLUID POWERED INVENTION

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

<table>
<thead>
<tr>
<th>Presentation</th>
<th>Is it well drawn and easy to understand?</th>
<th>/3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>Could it really work? Does it use fluid power?</td>
<td>/3</td>
</tr>
<tr>
<td>Creativity</td>
<td>Does it solve the task in a new and different way?</td>
<td>/4</td>
</tr>
</tbody>
</table>

**CONGRATULATIONS!!**

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

**Hydraulics**

1. Fill both cylinders with water:
   A. Push cylinder piston in
   B. Place cylinder tip underwater
   C. 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.