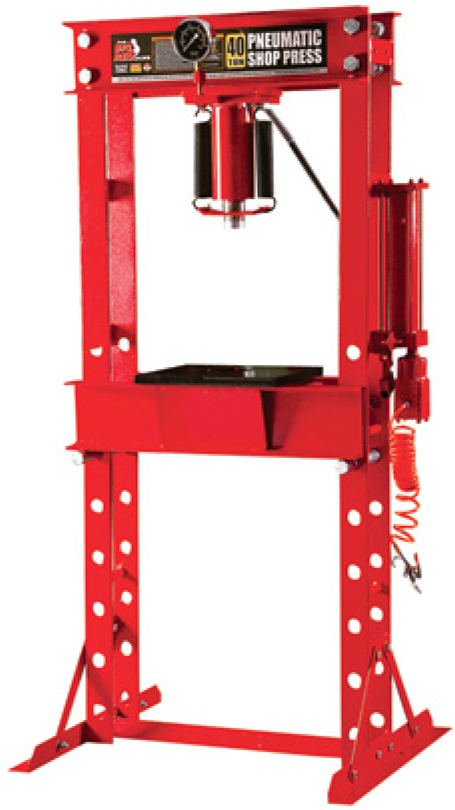
Figure 1

Specialist High Skill Major Contextualized Learning Activities (Physics–SPH4C)



Making A Hydraulic Press

Figure 1

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Lesson 1 – Volume, pressure
Lesson 2 – Density, flow rate
Lesson 3 – Pascal's Principle
Lesson 4 – Applied questions
Lesson 5/6 – Summative

Figure 1

Lesson 1

Density of Fluids

Fluids are a common substance that can be found in both the transportation and manufacturing technologies. For example transportation technologies that involve fluids include vehicle suspension systems, braking, steering and heavy lifting technology. Manufacturing technologies that involve fluids include molds, stamping dies and robotics.

Fluids – any substance that flows and takes the shape of its container. It is important to note that fluids include both liquids and gases. Some examples of fluids include water, oil, honey, molasses, air, and helium to name a few.

Hydraulics – the science of the mechanical properties of fluids

Pneumatics – the science of the mechanical properties of gases

	Advantages	**Disadvantages**
Pneumatics	• Cleaner • Easier to repair • Less expensive • Portable • Operate at lower pressure • Quieter than their hydraulic counterparts • Can be used in virtually any environment	• Low power • Operating costs are higher than hydraulic systems • Cannot hold a load in place
Hydraulics	• Operate at higher pressures • Generate high forces • Lower operating costs	• More complex systems which require maintenance workers with more advanced skills • More expensive initial costs • Hydraulic oil leaks can be hazardous

Figure 1

Compressibility – the ability of the particles of a substance to be pressed closer together.

- The fluid(air) in pneumatic systems have a high degree of compressibility
- The fluid(hydraulic oil) in hydraulic systems are nearly incompressible and transfer forces extremely well

Density – is the mass per unit volume of a substance. For example if we compare a rock and an apple of equal size the rock is heavier since the rock will have a much higher density than the apple.

$$D = \frac{m}{v}$$

Where: D → Density (kilogram per metre cubed - kg/m^3)
m → mass (kilogram - kg)
v → volume (metre cubed - m^3)

- Some other common units for density are g/L, g/mL and g/cm^3.

Examples

1. Calculate the density given the following information
   a) A volume of 0.75 m^3 of a substance has a mass of 9.45×10^2 kg.

$$D = \frac{m}{v}$$

$$D = \frac{9.45x10^2 kg}{0.75 m^3}$$

$$D = 1260\ {}^{kg}/_{m^3}$$

   b) A volume of 10.0 L of a substance has a mass of 7.90×10^3 g.

$$D = \frac{m}{v}$$

$$D = \frac{7.90\,x\,10^3 g}{10.0\ L}$$

$$D = 790\ {}^{g}/_{L}$$

Figure 1

Pressure of Fluids

Pressure is another common term that is used in daily life. Pressure effects such things as your drive to school, weather patterns, the ear popping effect felt on airplanes, ice skating and many more. Manufacturing Technologies that involve pressure include but not limited to pneumatic presses, robotics, and air cylinders performing mechanical work in factories.

Pressure – a magnitude of the force applied per unit area.

$$P = \frac{F}{A}$$

Where: P→ Pressure (Newton per metre squared - N/m^2) →In order to simplify the units, pressure is also measured using Pascal's(Pa). $1N/m^2 = 1$ Pa
F→ Force (Newton – N)
A→ Area (Metre squared – m^2)

Examples

1. A crate that is 1.0 m wide, 2.0 m long and 0.75 m high. The magnitude of its force of gravity is 2.0×10^3 N.
   a) Calculate the area of the crate in contact with the floor.

- *The shape of the bottom of a crate is a rectangle. To calculate the area of a rectangle the formula A=lw is used.*

$$A = lw$$
$$A = (2.0m)(1.0m)$$
$$A = 2.0m^2$$

   b) Calculate the pressure the crate exerts on the floor in Pascal's and kilopascals.

$$P = \frac{F}{A}$$
$$P = \frac{2.0 \times 10^3 N}{2.0m^2}$$
$$P = 1000 \, {}^{N}/_{m^2}$$
$$P = 1000Pa = 1kPa$$

   c) How would the pressure change if the crate were standing on its end?

Figure 1

Worksheet #1 – Density and Pressure

1. Calculate the density of a D2 steel solid cylinder that has a volume of 2.5×10^{-4} m^3 and a mass of 1.8 kg.

2. Calculate the mass of a cylinder block that has a density of $200 g/cm^3$ and a volume of $10 cm^3$.

3. Density of air is 1.29×10^{-3} g/cm^3 .   What is the volume of a pneumatics cylinder that has a mass of 5000g?

Figure 1

Density continued:

4. The density of a steel alloy figure 1 is $8.0 g/cm^3$ while the density of aluminum is $2.7 g/cm^3$. Compare the mass of an aluminum cylinder and a steel alloy cylinder with a volume $20 cm^3$. What are some of the advantages of using aluminum verses a steel alloy to manufacture pneumatic cylinders?

Figure 1 Steel alloy cylinder

Figure 2 Aluminum

5. Rewrite the equation $P = \frac{F}{A}$, to solve for (a) F and (b) A

6. Calculate the pressure in a set of pneumatic air lines if you apply 2 N of force over a surface area of 4.91×10^{-4} m^2

7. Assume that the air pressure in a pneumatic cylinder is 5.0×10^2 kPa higher than the air pressure outside the cylinder and is spread over an area of 0.20 m^2. Calculate the magnitude of the total force acting on the inside of the cylinder.

Figure 1

Lesson 2

Pascal's Principle Activity

This figure shows a device with two pistons, one large and one small, which can be used to test Pascal's principle for a liquid. Using a ruler, you can determine the surface area of each piston. (Area of a circle = πr^2). You can use force sensors pushing on the large and small pistons to determine the forces involved. Using this apparatus, take measurements and make calculations to test Pascal's principle. Verify that $P_s = P_L$.

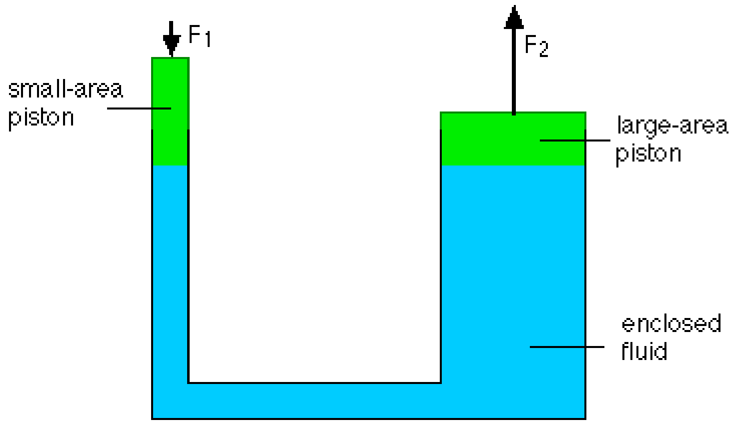
	Small Piston	**Large Piston**
Radius (m)		
Area (m^2) **$A=\pi r^2$**		
Force (N)		
Pressure (Pa) $P = \frac{F}{A}$		

Figure 1

Pascal's Principle

Pressure applied to an enclosed liquid is transmitted equally to every part of the liquid

- This principle is named after Blaise Pascal a French mathematician and physicist
- Liquids are nearly incompressible
- This principle allows a **small input force** to exert a **large output force**.
- Pascal's principle works similar to a lever, pulley or incline plan in that it provides a significant mechanical advantage.



- Pascal's principle can be summarized in equation form as following:

$$P_1 = P_2$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Examples

1. Determine the input force (F_1) on a bicycle disc brake master cylinder of area 2.5×10^{-3} m^2 if the output force is 1.2×10^3 N with a surface area of 1.0×10^{-1} m^2

Given: $A_1 = 2.5 \times 10^{-3}$ m^2
$F_2 = 1.2 \times 10^3$ N
$A_2 = 1.0 \times 10^{-1}$ m^2

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{F_1}{2.5 \times 10^{-3} m^2} = \frac{1.2 \times 10^3 N}{1.0 \times 10^{-1} m^2}$$

$$\frac{F_1}{2.5 \times 10^{-3} m^2} = 1.2 \times 10^4 Pa$$

$$F_1 = 3.0 \times 10^1 N$$

Figure 1

Worksheet #2 – Pascal's Principle

1. Explain why Pascal's principle can be used for hydraulic systems and not pneumatic systems?

2. Rewrite $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ to solve for (a) F_1, (b) A_1, (c) F_2, and (d) A_2

3. A car of mass 1.2×10^3 kg is hoisted on the large(output) cylinder of a hydraulic press. The area of the large piston is $0.18 m^2$, and the area of the small(input) cylinder is $0.01 m^2$.
   a) Calculate the magnitude of the force of the small piston needed to raise the car on the large piston.
   b) Calculate the pressure, in Pascal's in the hydraulic oil lines.

4. The tar sands in Alberta use large dump trucks to haul the material to facilities where the oil is extracted. When the dump trucks reach the refining facility they must dump the material. In order to do this they use large hydraulic cylinders. These cylinders exert a maximum force of magnitude 5.0×10^5 N on the input cylinder. The surface area of the input piston is $0.10 m^2$, and the surface area of the output piston is $4.0 m^2$. Calculate
   a) The magnitude of the maximum load that the dump truck can carry and successfully unload
   b) The mass of the load

Figure 1

Lesson 3

In order to allow for simple hydraulic and pneumatic systems to be constructed multiple components must be used together to achieve the desired effect.

Investigation – Two and three cylinder fluid systems

Questions
How do hydraulic and pneumatic systems compare? How can valves be used to control fluid flow in a pneumatic system?

Predictions

a) Predict how the action of a pneumatic system with a long hose connection compares to the action of one with a short hose connection.

b) Predict how the action of a hydraulic system with a long hose connection compares to the action of one with a short hose connection.

Materials

- 2 Large syringes (ex. 20 mL)
- 2 small syringes (ex. 5 mL)
- 3 short lengths of tubing
- 1 long length of tubing
- Straight connector
- T connector
- 2 – way Valve
- 2 Force sensors
- Beaker with water
- Bucket
- Sponge/paper towels

Figure 1

Procedure

Part A

1. Connect the two large syringes using a short length of tubing. As you depress one piston, what happens to the other piston?
2. Try holding one piston steady while moving the other piston. Describe what you observe.
3. Using the force sensor and ruler calculate the pressure on each syringe.
4. Replace the short tubing with the long tubing and repeat steps 1 to 3.

Part B

5. With the same apparatus used in steps 1 to 3, fill the syringes with water so they contain no air bubbles. Repeat steps 1 to 3
6. Repeat step 4 using water.

Observations
Part A

	Procedural Step	**Observations and Data**	
Short Tubing	Depressing one piston		
	Holding one piston while moving the other		
	Determine the pressure on each piston	Piston 1 F= A= P=	Piston 2 F= A= P=
Long Tubing	Depressing one piston		
	Holding one piston while moving the other		
	Determine the pressure on each piston	Piston 1 F= A= P=	Piston 2 F= A= P=

Figure 1

Part B

	Procedural Step	Observations and Data
Short Tubing	Depressing one piston	
	Holding one piston while moving the other	
	Determine the pressure on each piston	Piston 1 Piston 2 F= F= A= A= P= P=
Long Tubing	Depressing one piston	
	Holding one piston while moving the other	
	Determine the pressure on each piston	Piston 1 Piston 2 F= F= A= A= P= P=

Analysis

1. How does a hydraulic system compare with a pneumatic system in its operation?
2. Was Pascal's principle verified in both pneumatic and hydraulic systems? Give evidence to support your answer.
3. Is an air system or a water system more difficult to experiment with? Explain your answer.
4. Evaluate your predictions made at the beginning of this activity.

Figure 1

Lesson 4

Pnuematic and hydraulic components

Some common components that we will investigate are:

1. Cylinder – a cylinder barrel with a piston rod that uses compressed gases(pneumatics) or pressurized liquid(hydraulic) for pushing /pulling

2. Valves - A valve is a device that regulates the flow of a fluid by opening, closing, or partially obstructing various passageways.

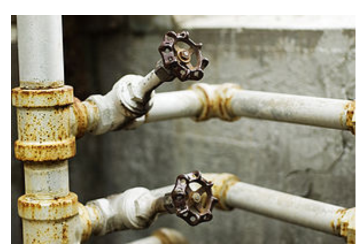


Figure 1

3. Motors – changes electrical energy into mechanical energy. Motors are often used to run fans, pumps, power tools, and house hold appliances.

4. Hoses – distribute forces throughout the pneumatic/hydraulic system

5. Pumps – a device used to move fluids, specifically liquids or slurries

6. Reservoirs - The hydraulic fluid reservoir holds excess hydraulic fluid to accommodate volume changes from: cylinder extension and contraction, temperature driven expansion and contraction, and leaks.

Figure 1

Summative Quiz – Pascal's Principle – Pressure – Density

Name: ________________________ **Date: ____________**

1. Find the force on a large piston with an area of $1.2m^2$. The small piston in the system has a force of 250N and an area of $0.25\ m^2$.

2. Find the density of a block of metal if it has dimensions of 2cm, 8cm, and 10cm. It has a mass of 545 g. give the density in g/cm^3.

3. What is the mass of water in a swimming pool if it contains $400\ m^3$ of water and pool water has a density of $1005.2\ kg/m^3$?

4. Find the pressure if a foot has an area of $265cm^3$ and the person has a mass of 75.6kg.

5. What area of glass is needed to support a television that has a downward force of 20 000N if the glass can withstand a maximum pressure of 40kPa?

Figure 1

Constructing a Hydraulic Press System

Purpose:
To construct a hydraulically operated Press system capable of compressing play doe.

Research Report (2 Page Maximum)
How have pneumatic and hydraulic systems in robotics changed manufacturing? Include information on the following:

- Economic impact
- Changes in production
- Safety
- Production quality

Also include information on the change to industry as a result of hydraulic and pneumatic robotic systems. What was the impact on factory workers?

Materials:
- 1 Large syringe
- 1 small syringe
- 1 length of long tube
- 5 Wooden pieces
- 2 Wood connectors
- "T" Connectors
- Play doe
- Toy stamps

Procedure

****Refer to Figure 1 below****

1. Cut 4 pieces of wood. These will be used as the frame for your hydraulic press
2. Secure the pieces of wood together using tape/hot glue/etc.
3. Insert the syringe into the top of the wooden frame and secure it with glue.
4. Attach the 2 syringes with hose connectors.
5. Cut a piece of wood to fit on bottom of frame and attach with glue.
6. Place a stamp or plastic mold on top of wood

Figure 1

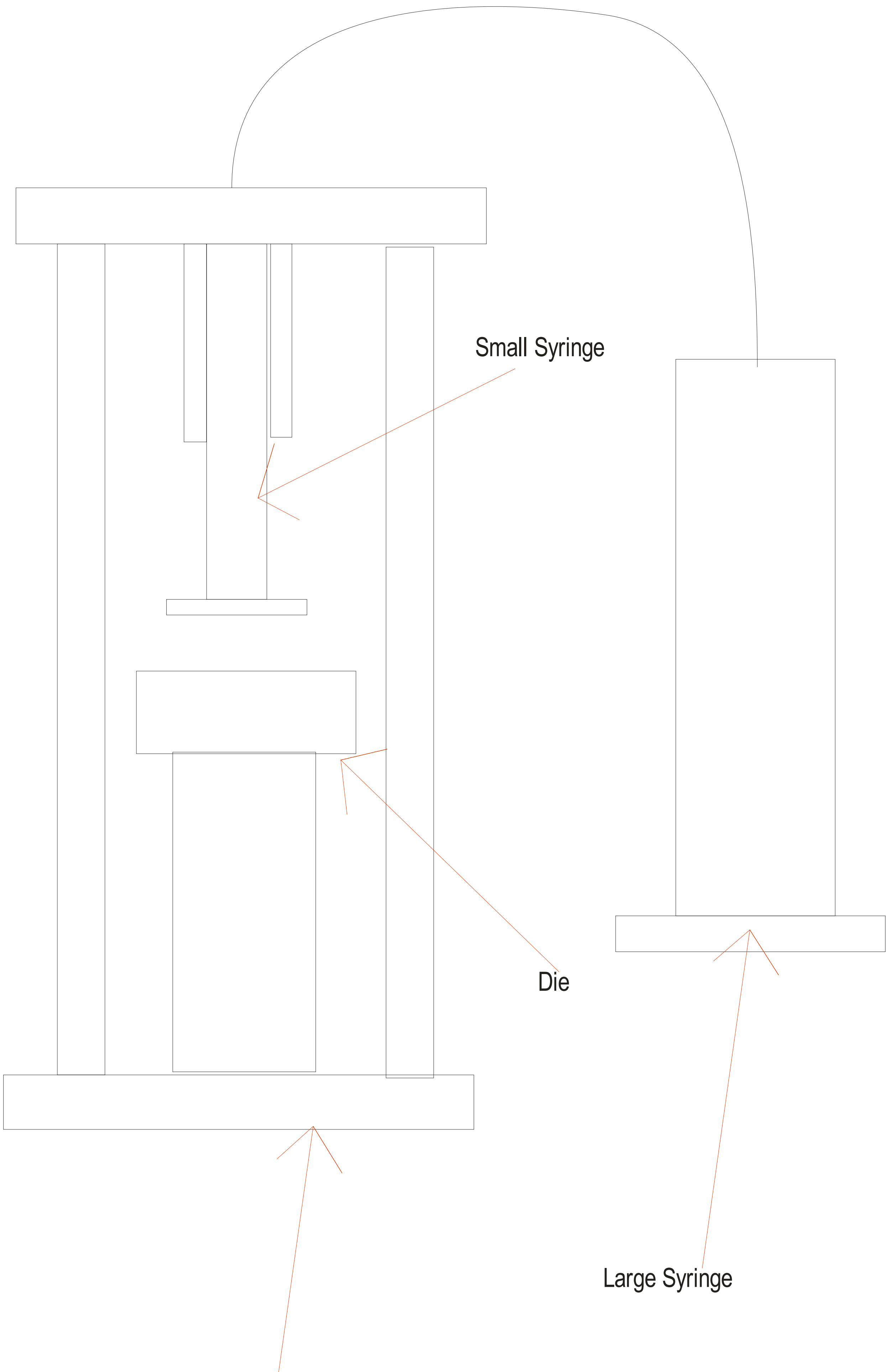


Figure 1