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HYDRAULIC PRESS

CAT NO. PH0215

Experiment Guide

INTRODUCTION

The Hydraulic Press is a great way to show Pascal's Law in operation. Students will understand mechanical advantage when they use this system of connected pistons. Apply force to one syringe-type piston of 10 ml to make the liquid rise in the other 50 ml, showing the concept behind such everyday items as power steering, shock absorbers, hydraulic jacks etc.

KIT CONTENTS

Hydraulic Press Apparatus

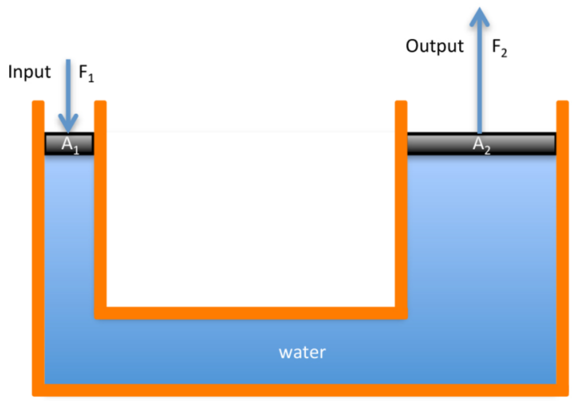
REQUIRED COMPONENTS (NOT INCLUDED)

100 mL beaker with water
Several inches of rubber tubing (5cm inner diameter)
Four masses of equal value

GENERAL BACKGROUND

The Hydraulic Press demonstrates Pascal's Principle in action. Pascal's Principle is that the pressure throughout a closed system is constant. As a result, any change in pressure to one part of a system is transmitted to all other parts of the system.

A hydraulic system uses this to our advantage. A simplified hydraulic press (or lever) is shown in the figure below. You can think of this as a U-tube, with one side of the tube with a larger cross sectional area than the other.



A downward force of magnitude F_1 is applied (perhaps by placing a mass) on the piston on the left with cross-sectional area A_1. Due to the incompressible fluid inside the device, such as water or oil, the force on the left will produce an upward force of magnitude F_2 on the piston on the right with cross-sectional area A_2. To keep the system in equilibrium, an equivalent downward force must be placed on the piston on the right.

The forces produce a change in pressure on the liquid give by

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

and thus

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

From this we can we that the output force F_2 is greater than the input force F_1 if the area of the right side A_2 is larger than the area of the left side A_1.

For example, what if the area on the right is fifty times larger than the cross-sectional area on the left and we pushed down on the left side with a 1 N force? Then the upward force on the left hand side would be 50 N! Here we can start to see how we can use this to our advantage.

Perhaps you have seen the use of a hydraulic jack to lift a car. You may have noticed that one needs to repeatedly pump the lever to get the car to raise. Why is this? Let's investigate this by looking at how the connection between the piston's effect their movement.

If we move the left piston down a distance d_1, how much will the piston on the right lift up a distance d_2? Since the liquid is incompressible, the same volume, V, of liquid must be displaced at both pistons. We can write that as:

$$V = A_1 d_1 = A_2 d_2$$

or

$$d_2 = d_1 \frac{A_1}{A_2}$$

Since in our example A_2 is larger than A_1, that means d_2 is smaller than d_1, and the piston on the right will move a shorter distance than the piston on the left moved.

In conclusion, we can describe the mechanical advantage of the Hydraulic Press as a device which given a force applied over a distance can be transformed to a larger force over a smaller distance.

PROCEDURE

A note on valve positions:

These instructions will refer to the valve in several positions. To make things clearer, we will call the valve in the horizontal position with the third prong pointing up as Valve Position 1, as shown in Figure 1. This connects the 10 mL piston on the right with the reservoir. And we will call the valve in the vertical position with the prong pointing right as Valve Position 2, as shown in Figure 2. This connects the two pistons together.

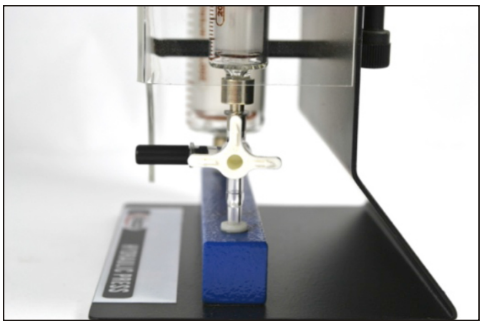


Figure 1
Valve Position 1

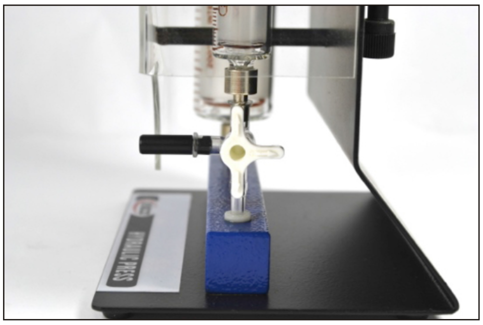


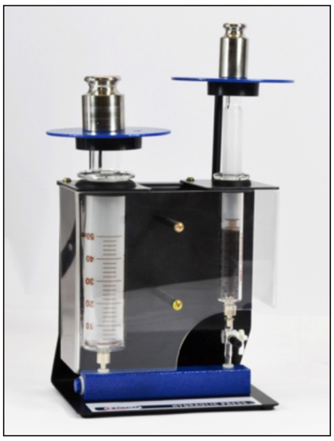
Figure 2
Valve Position 2

1. Fill a 100mL beaker with water. Insert one end of a short rubber tube onto the valve connection on the hydraulic press, and submerge the other end in the water.

2. Measure the diameter of each syringe. You may need to lift up each plate. Calculate the ratio of the larger cross-sectional area to the smaller.

$$\frac{\pi\,(d_2/2)^2}{\pi\,(d_1/2)^2}$$

3. Place a small mass on right piston (20-50g is sufficient). Multiply that amount by the ratio calculated above. Place an amount of mass equivalent or slightly less than that number on the left piston.



4. Adjust the valve to Valve Position 1. Raise the right platform to intake 10mL of liquid. While holding the piston at that height, turn the valve to Valve Position 2 by rotating it clockwise. Release the right piston. How much liquid did the syringe on the left gain? By what height did the piston raise?

5. Rotate the valve counter-clockwise back to Valve Position 1. Repeat step four until you have raised the water level in the left syringe all the way to 50 mL.

ACTIVITY – BOYLE'S LAW

GENERAL BACKGROUND

Discovered by chemist Robert Boyle in 1662, there exists a fundamental relationship between the pressure exerted by a gas of given mass and the volume of that gas. Boyle found that the pressure of a gas tends to increase as the volume of the gas decreases. We describe this relationship as the pressure being inversely proportional to the volume, and this holds true as long as the temperature and amount of gas remain fixed.

We can write this inversely proportional relationship as an equation:

$$P \propto 1/V$$

or, alternatively, that the product of the pressure of the gas, P with the volume of the gas, V, is a constant, k. Or

$$PV = k.$$

In this activity, we will be comparing the pressure and volume of a given amount of air that is contained inside a syringe under different amounts of compression of the plunger. We will discover that since Boyle's law holds true in this case, the pressure and volume for any amount of compression will remain equivalent. Or written in equation form

$$P_1 V_1 = P_2 V_2 = P_3 V_3 = P_4 V_4,$$

where the numerical subscripts denote different amounts of syringe compression.

REQUIRED MATERIALS

Eisco Hydraulic Press

REQUIRED COMPONENTS (NOT INCLUDED)

Pressure Sensor
Rubber tubing

EXPERIMENT

1. Set valve position so the larger syringe is connected to the air outlet. Pull the plunger of the syringe back to so the front edge of the piston is at the 50 mL mark.

2. Holding the syringe at 50 mL, insert one end of the rubber tube into air outlet. Insert the other end into the Pressure Sensor.

3. Set the Pressure Sensor to record in kPa (kilopascals).

4. Record the pressure for a 50 mL syringe volume in the table. For the actual volume, one must also account for the air in the rubber tube and in the pressure sensor itself, so add 3 mL to the volume measurement to give a better approximation for the total volume in the system.

5. Push in the plunger on the syringe, compressing the air a total of 4 mL. Hold it at that mark while taking a reading of the pressure. Record in the table, remembering to add 3 mL to the volume reading.

6. Continue taking readings for pressure with respect to volume for 4 mL additional compression. Hold the syringe at the mark while taking a reading. Compress to 30 mL or until it is too difficult to compress the plunger any further.

DATA

Volume (mL)	Pressure (kPa)	P * V (mL *kPa)

DATA ANALYSIS

1. Multiply the pressure times the volume for each measurement. Record in the third column of the table.

2. Do you find that the product of volume and pressure are equivalent under compression of the air? Average the six products and then determine which is the measurement has the largest difference from the average. What is the percent difference between the biggest result and the average result?

SAMPLE RESULTS

Volume (mL)	Pressure (kPa)	P * V (mL *kPa)
40.5	101.8	4122.9
36.5	112.2	4095.3
32.5	124.3	4039.8
28.5	140	3990.0
24.5	162.1	3971.5
20.5	194.4	3985.2

The average pressure between the six measurements is 4034.1 mL*kPa. All measured product of pressure and volume were within 100 mL*kPa from the average. The first measurement has the largest difference, with a percent difference of 2.2%, so we can conclude that Boyle's law is accurate.

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