Fluids
Pascal's Principle
Measuring Pressure
Buoyancy

Lana Sheridan

De Anza College

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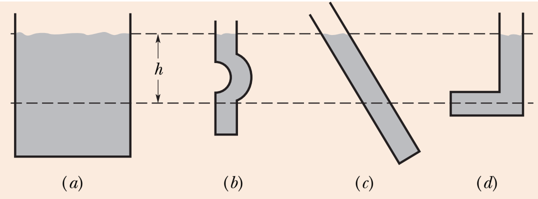
Last time

- shear modulus s
- introduction to static fluids
- pressure
- bulk modulus
- pressure and depth

Warm Up Question

The figure shows four containers of olive oil. Rank them according to the pressure at depth h, greatest first.[1]



A a, b, c, d

B a, d, c, b

C a, c, d, b

D All the same

[1] Halliday, Resnick, Walker, 9th ed, page 363.

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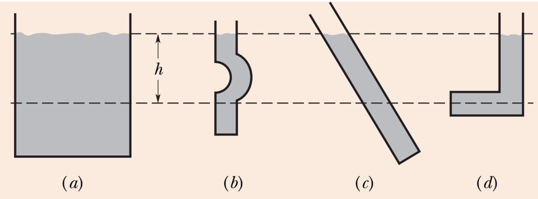

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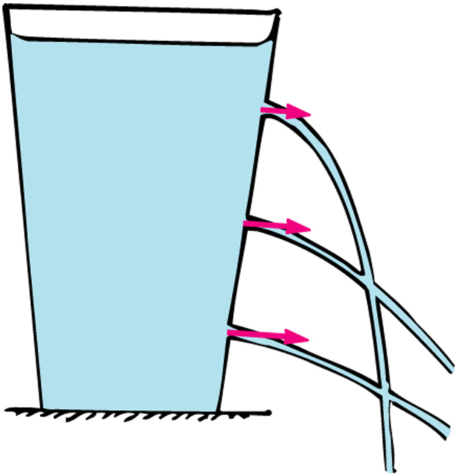
Overview

- pressure and depth
- Pascal's principle
- measurements of pressure
- buoyancy and Archimedes' principle

Pressure varies with Depth



Pascal's Barrel

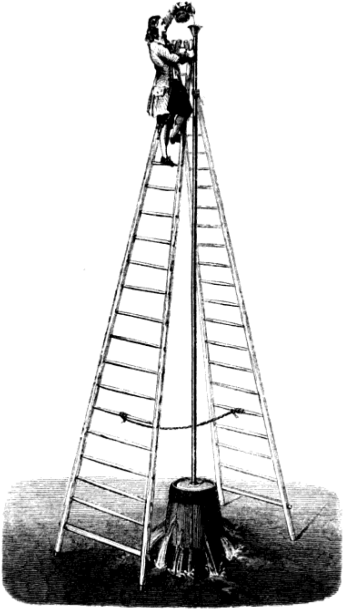


Fig. 45.—Hydrostatic paradox. Pascal's experiment.

Density of Water

For water:

$$\rho_w = 1.00 \times 10^3 \text{ kg/m}^3$$

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Originally, the gram was defined to be the mass of one cubic centimeter of water at the melting point of water.

Questions

Calculate the water pressure at the base of the Hoover Dam. The depth of water behind the dam is 220 m.[2]

[2] Question from Hewitt, Conceptual Physics, 11th ed.

[3] See example 14.4, page 422, Serway & Jewett, 9th ed.

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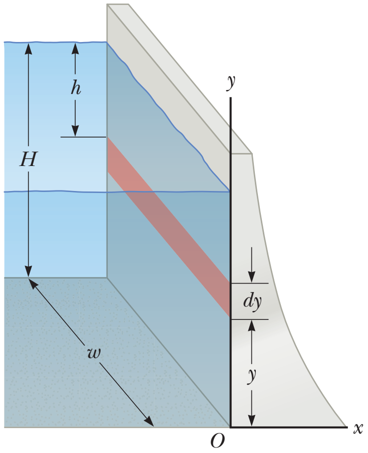

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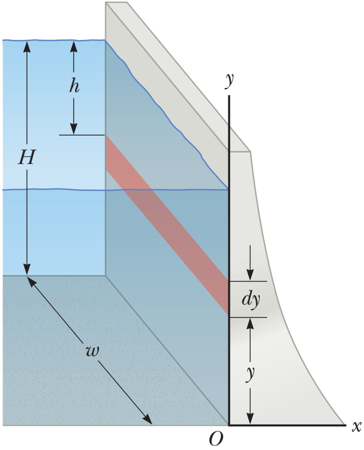

$$F = 9.0 \times 10^{10} \text{ N}$$

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Pressure in a liquid

We have this expression for total pressure:

$$P_{\text{total}} = P_0 + \rho g h$$

What if the pressure at the surface of the liquid, P_0, was increased to P_1.

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The *differences* in pressure between the different layers of liquid remain the same, but the pressure at each depth h increases.

Pascal's Law

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Pascal's law applied to confined, incompressible fluids.

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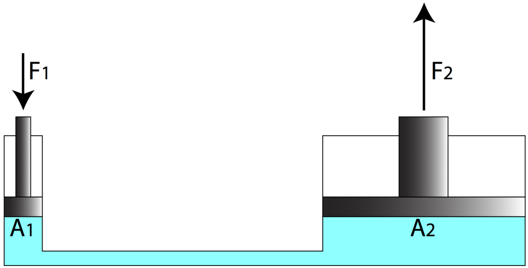
Pascal's Law

A change in pressure applied to one part of an (incompressible) fluid is transmitted undiminished to every point of the fluid.

This does *not* mean that the pressure is the same at every point in the fluid.

It means that if the pressure is increased at one point in the fluid, it increases by the same amount at all other points.

Pascal's Principle



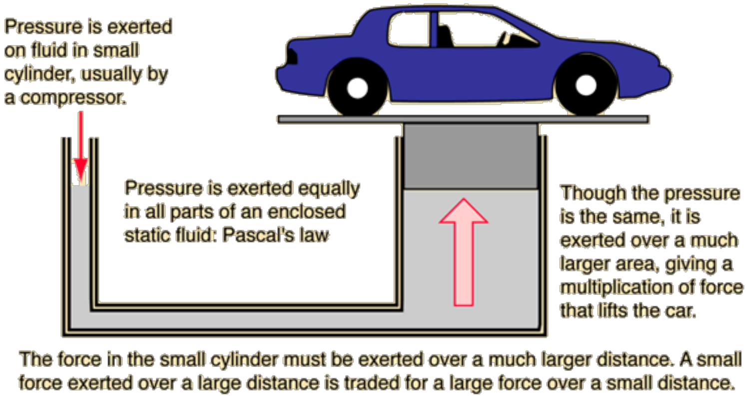
Since the changes in pressures at the left end and the right end are the same:

$$
\begin{aligned}
\Delta P_1 &= \Delta P_2 \\
\frac{F_1}{A_1} &= \frac{F_2}{A_2}
\end{aligned}
$$

Since $A_2 > A_1$, $F_2 > F_1$.

Hydraulic Lift

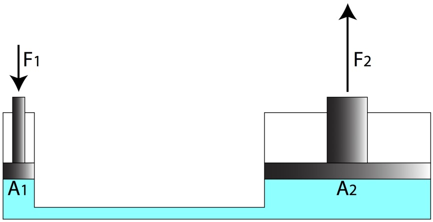
This has applications:



[1]Figure from hyperphysics.phy-astr.gsu.edu.

Question

If a pair of pistons are connected on either end of a hydraulic tube. The first has area 0.2 m^2 and the second has an area of 4 m^2.



A force of 30 N is applied the first piston. What is the force exerted by the second piston on a mass that rests on it?

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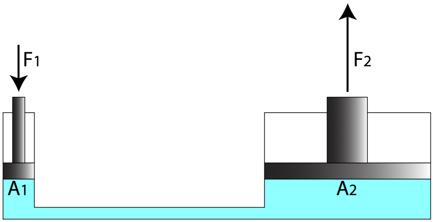
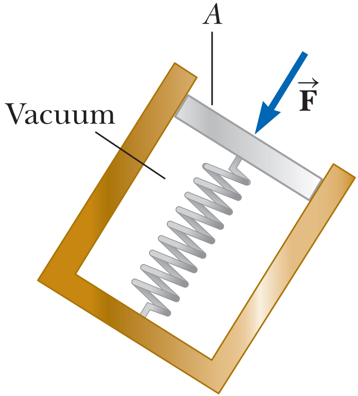


A force of 30 N is applied the first piston. What is the force exerted by the second piston on a mass that rests on it?

If the first piston is depressed a distance of 1 m by the 30 N force, how far does the second piston rise?

Measuring Pressure

Pressure in a fluid could be measured using a device like this:

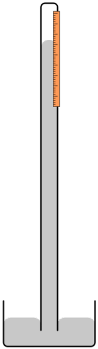


The pressure is proportional to the compression of the spring.

[1] Diagram from Serway & Jewett, 9th ed.

Barometers

Barometers are devices for measuring local atmospheric pressure.

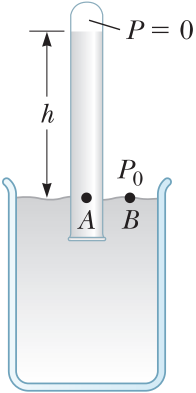


Typically, simple barometers are filled with mercury, which is very dense.

The weight of the mercury in the tube exerts the same pressure as the surrounding atmosphere. On low pressure days, the level of the mercury drops. On high pressure days it rises.

Mercury Barometer

The pressure at points A and B is the same.



The pressure at B is P_0.

Above the mercury in the tube is a vacuum, so pressure at A is $\rho_{Hg} g h$.

($\rho_{Hg} = 13.6 \text{ kg/m}^3$)

Therefore, $P_0 = \rho_{Hg} g h$.

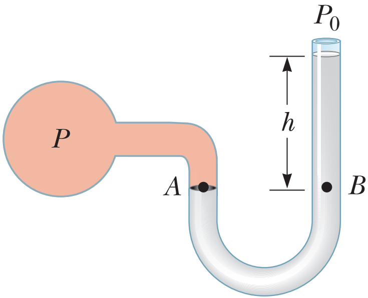
$$h \propto P_0$$

Pressure is sometimes quoted in "inches of mercury".

[1]Diagrams from Serway & Jewett, 9th ed.

Manometer

The pressure being measured, P, can be compared to atmospheric pressure P_0 by measuring the height of the incompressible fluid in the U-shaped tube.



If h is positive, $P > P_0$, if "negative", $P < P_0$.

$P - P_0$ is called the **gauge pressure**.

Summary

- pressure and depth
- Pascal's principle
- measuring pressure
- buoyancy and Archimedes' principle

Test Tuesday, April 17, in class.

Collected Homework due Monday, April 16.

(Uncollected) Homework Serway & Jewett:

- Ch 14, onward from page 435, OQs: 7; CQs: 5; Probs: 8, 15, 19, 21, (25, 27, 29, 35, 36, 65, 71, 73,) 77 - brackets are buoyancy questions