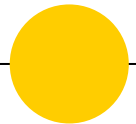


Physics 101H

General Physics 1 - Honors



Lecture 40 - 11/13/23

Pascal's principle



Summary

Topics

Friday: Fluid mechanics [[chapter 14](#)]

- Pressure
- Archimedes' Principle

Today: Pascal's law [[chapter 14](#)]

- Pascal's law
- Hydraulic lift
- Measuring pressure

Announcements

**Wednesday: Problem set 7 due
No problem set assigned**

Thursday: Quiz 8

Next week: All classes remote



Think-pair-share

Instructions: Consider the following question. After you have had a chance to think, I will ask you to raise your hands to indicate your answer. We will then discuss with our neighbours, before voting again.

Question: A 200-ton ship enters the lock of a canal. The fit between the sides of the lock and the ship is pretty tight, so that the weight of the water left in the lock after it closes (with the ship in it) is much less than 200 tons. Can the ship still float if the quantity of water left in the lock is much less than the ship's weight?

- (a) yes
- (b) no
- (c) I have no idea

Example: A cube of wood with side length 20 cm and density 650 kg/m^3 floats. [How much of it sticks out of the water?] What mass of lead should be added to the top of the cube so that the cube will be just level with the water?

Pascal's principle/law



Any change in pressure is transmitted, undiminished, to every other point in the fluid.

Transmitting pressure allows us to use **mechanical advantage** to create **hydraulic lift**



Measuring pressure



There are actually lots of “pressures”

- **Gauge pressure** measures the difference between the pressure inside, for example, a tyre and the atmospheric pressure outside the tyre
- **Absolute pressure** accounts for atmospheric pressure
- **Barometric pressure** measures the current local atmospheric pressure
[not to be confused with...]
- **Atmospheric pressure** is defined to be 101,325 Pa



Think-pair-share

Instructions: Consider the following question. After you have had a chance to think, I will ask you to raise your hands to indicate your answer. We will then discuss with our neighbours, before voting again.

Question: Two cups are filled to the same level with water. One of the cups has ice cubes floating in it. Which weighs more?

- (a) The cup with ice cubes in it
- (b) The cup without ice cubes in it
- (c) They both weigh the same



Summary

Quiz 8 will cover:
Noether's theorem
Pressure and density
Three problem set questions

Topics

Today: Pascal's law [[chapter 14](#)]

- Pascal's law
- Hydraulic lift
- Measuring pressure

Wednesday: Fluid dynamics [[chapter 14](#)]

- Continuity equation
- Bernoulli equation

Announcements

Wednesday: Problem set 7 due
 No problem set assigned

Thursday: Quiz 8

Next week: All classes remote

**NEXT WEEK:
CLASSES ARE PRE-RECORDED AND POSTED
ONLINE**

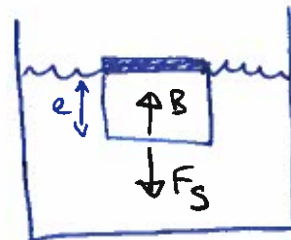


PHYSICS 101 - HONORS

Lecture 40 11/13/23

Cube example (again/revised)

Now the cube is submerged,
so volume of water displaced is
equal to the volume of the cube



$$B = \rho_{\text{H}_2\text{O}} V_{\text{H}_2\text{O}} g = \rho_{\text{H}_2\text{O}} e^3 g$$

In this case

$$\begin{aligned} F_g &= F_g^{\text{lead}} + F_g^{\text{cube}} \\ &= M_{\text{lead}} g + M_{\text{cube}} g \\ &= M_{\text{lead}} g + \rho_{\text{cube}} e^3 g \end{aligned}$$

$$\rho_{\text{cube}} = \frac{M_{\text{cube}}}{V_{\text{cube}}} = \frac{M_{\text{cube}}}{e^3}$$

$$\text{Equilibrium} \Rightarrow \Sigma \vec{F} = 0 \quad \text{or} \quad \vec{B} + \vec{F}_g = 0$$

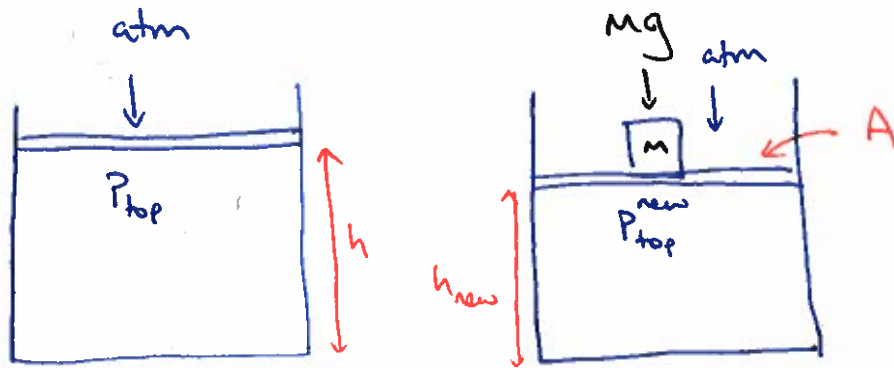
$$\text{Vertically: } B - F_g = 0 \Rightarrow B = F_g$$

$$\Rightarrow \rho_{\text{H}_2\text{O}} e^3 g = M_{\text{lead}} g + \rho_{\text{cube}} e^3 g$$

$$\begin{aligned} \Rightarrow M_{\text{lead}} &= \rho_{\text{H}_2\text{O}} e^3 - \rho_{\text{cube}} e^3 \\ &= (\rho_{\text{H}_2\text{O}} - \rho_{\text{cube}}) e^3 \\ &= (1000 - 650) \cdot 0.2^3 \\ &= \underline{\underline{2.8 \text{ kg}}} \end{aligned}$$

Pascal's principle (slide 6)

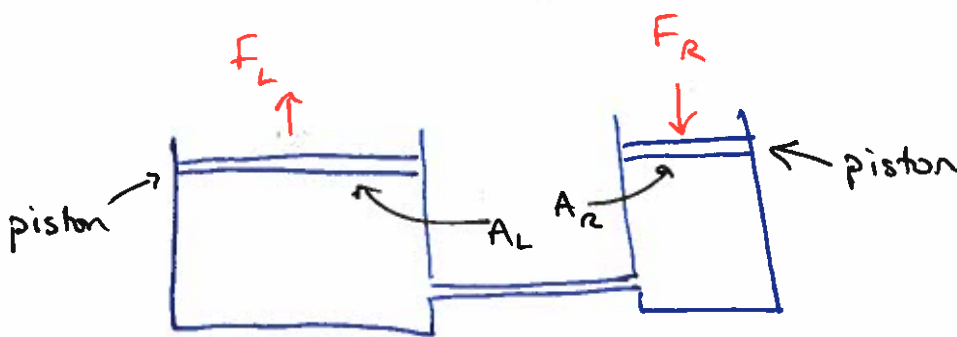
If we imagine compressing a fluid, then we change the pressure



$$\Delta P_{\text{top}} = \frac{mg}{A} \quad \text{due to mass } m \text{ exerting force } mg \text{ over area } A$$

Pascal's principle tells us that

$$\Delta P_{\text{bottom}} = \Delta P_{\text{top}} = \frac{mg}{A} = \Delta P_{\text{everywhere}}$$



$$A_L > A_R$$

Pressure due to F_R is $\Delta P_R = F_R / A_R$

[Initially $P_{0L} = P_{0R}$, then F_R applied]

$$\Rightarrow P_{0R} + \Delta P_R = P_{0L} + \Delta P_L \quad (\text{Pascal's principle})$$

$$\Rightarrow \Delta P_R = \Delta P_L$$

But $\Delta P_L = \frac{F_L}{A_L}$

$\rightarrow \frac{F_R}{A_R} = \frac{F_L}{A_L}$ or $F_L = \frac{A_L}{A_R} F_R > F_R$

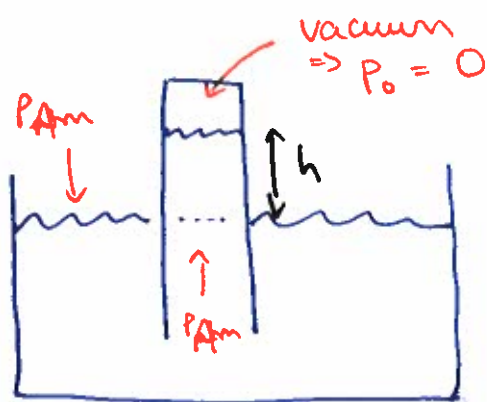
← because $A_L > A_R$
 $\Rightarrow \frac{A_L}{A_R} > 1$

Measuring pressure (slide 7)

$P_{\text{absolute}} = P_{\text{gauge}} + P_{\text{atm}}$

But how do we measure any of these?

Barometer measures barometric pressure - current local pressure of the atmosphere



← not the same as the defined standard atmospheric pressure

$P_A = P_0 + \rho gh = \rho gh$

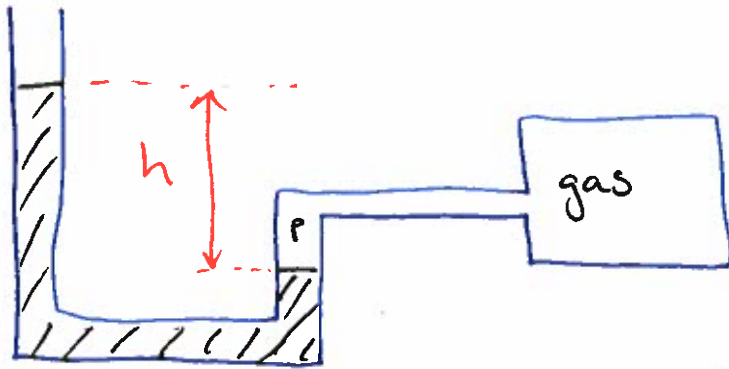
\Rightarrow measure the height and find the pressure!

← typically mercury (or alcohol) \Rightarrow so common that "mm Hg" is a unit of pressure:

$1 \text{ atm} = 760 \text{ mm Hg}$

Q: what are the advantages/disadvantages?

Manometer measures gauge pressure - the difference from atmospheric pressure



$$P_g = \rho g h$$

↑ gauge pressure

$$P_{abs} = P_g + P_{atm}$$
$$= P_{atm} + \rho g h$$

Key equations

pressure (in general)

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

pressure (as a function of depth in a fluid)

$$P = P_0 + \rho g h$$

Archimedes' principle

buoyant force = weight of fluid displaced

Pascal's principle

pressure transferred equally throughout fluid