Physics 101H

General Physics 1 – Honors

Lecture 38 – 11/11/22

Pascal’s principle

Summary

Topics

Yesterday: Fluid mechanics [chapter 14]

- Pressure
- Archimedes' Principle

Today: Pascal's principle [chapter 14]

- Pascal's principle
- Hydraulic lift
- Measuring pressure

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?

Question: Why is it easier to float on your back in water than any other position?

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

Topics

Yesterday: Pressure [chapter 14]

- Pressure
- Archimedes’ Principle

Today: Pascal’s law [chapter 14]

- Pascal’s law
- Hydraulic lift
- Measuring pressure

Next week:

- Fluid dynamics [chapter 14]
- Oscillations [chapter 15]

PHYSICS 101 - HONORS

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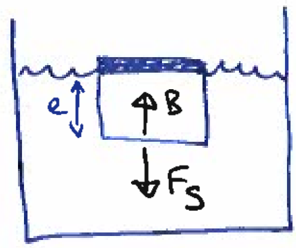
Cube example (again/revised)

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



$$B = \rho_{H_2O} V_{H_2O}\, g = \rho_{H_2O}\, e^3 g$$

In this case

$$F_g = F_g^{lead} + F_g^{cube}$$

$$= M_{lead}\, g + M_{cube}\, g$$

$$= M_{lead}\, g + \rho_{cube}\, e^3 g$$

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

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

Vertically: $B - F_g = 0 \Rightarrow B = F_g$

$$\Rightarrow \rho_{H_2O}\, e^3 g = M_{lead}\, g + \rho_{cube}\, e^3 g$$

$$\Rightarrow M_{lead} = \rho_{H_2O}\, e^3 - \rho_{cube}\, e^3$$

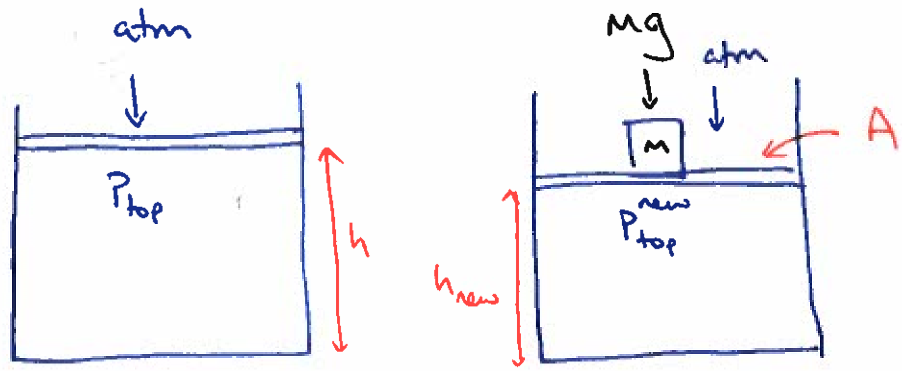
$$= (\rho_{H_2O} - \rho_{cube})\, e^3$$

$$= (1000 - 650) \cdot 0.2^3$$

$$= \underline{\underline{2.8 \text{ kg}}}$$

Pascal's principle (slide 6)

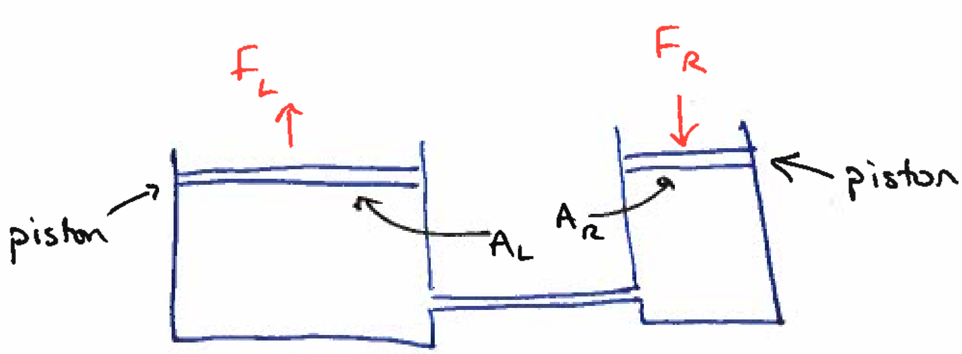
If we imagine compressing a fluid, then we change the pressure



$\Delta P_{top} = \frac{Mg}{A}$ due to mass M exerting force Mg over area A

Pascal's principle tells us that

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



$A_L > A_R$

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

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

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

$\Rightarrow \Delta P_R = \Delta P_L$

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

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

↖ because $A_L > A_R$

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

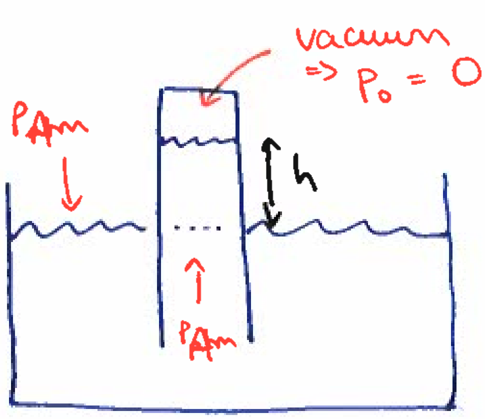
__Measuring pressure__ (slide 7)

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

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



$P_A = \cancel{P_0}^{=0} + \rho g h = \rho g h$

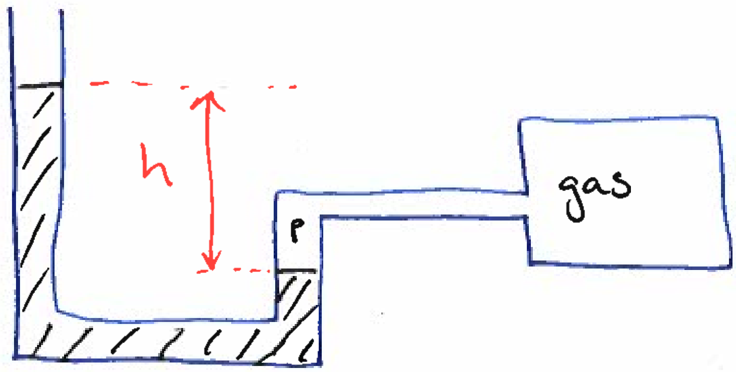
$\Rightarrow$ measure the height and find the pressure!

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

1 atm = 760 mm Hg

Q: what are the advantages/disadvantages? →

Manometer measures gauge pressure – the difference from atmospheric pressure



$P_g = \rho g h$

↑ gauge pressure

$P_{abs} = P_g + P_{atm}$

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