Physics 101H

General Physics 1 – Honors

Lecture 39 – 11/10/23

Pressure

Summary

Topics

Yesterday: Noether's theorem

- The action
- Calculus of variations
- Noether's theorem

Today: Fluid mechanics [chapter 14]

- Pressure
- Archimedes' Principle

Question 39.1: Which weighs more, pepsi or diet pepsi?

Fluids

Everything we have done so far has focussed on **solids**

- point particles
- rigid extended objects
- deformable extended objects

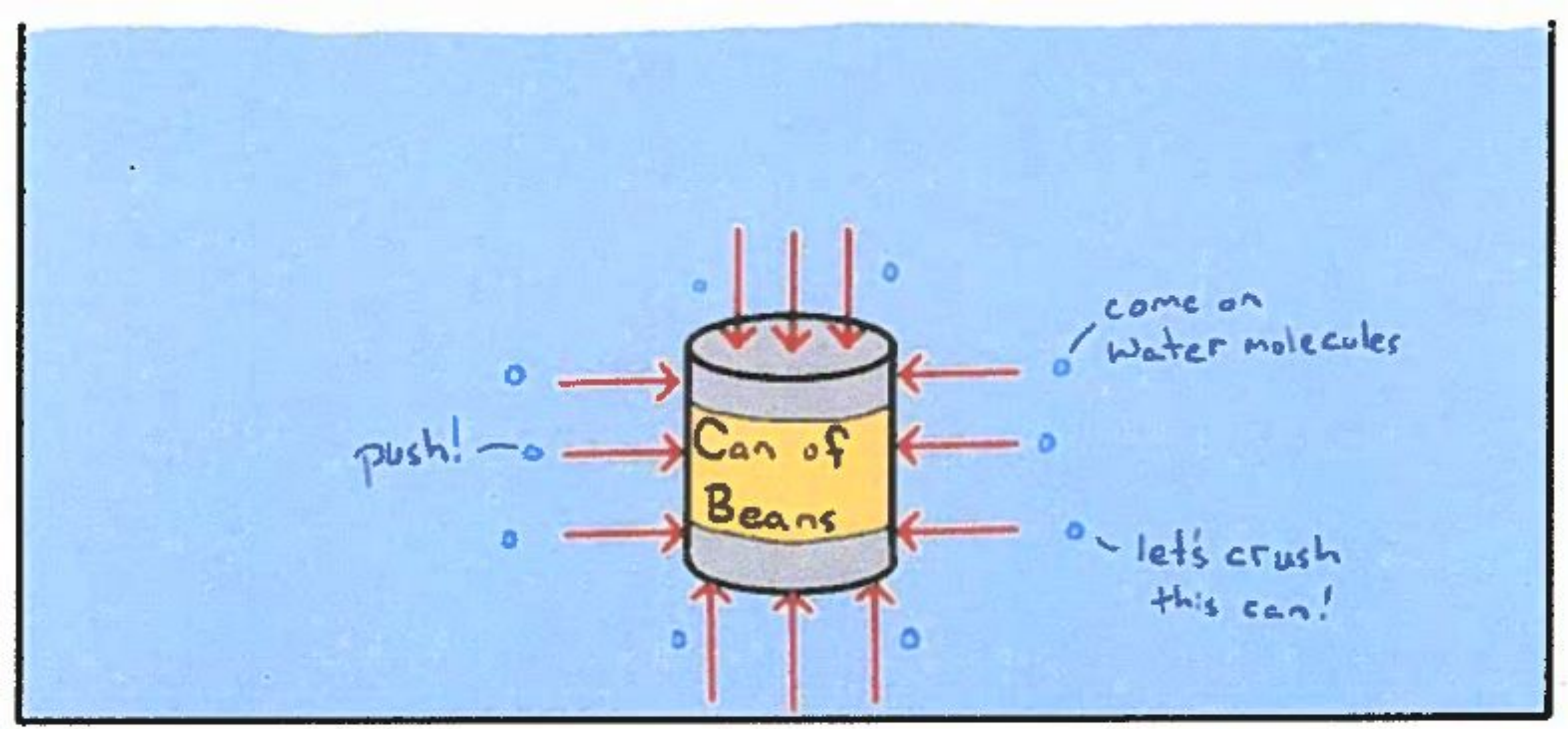
Today we switch our attention to **fluids**

- liquids and gases have weak cohesive internal forces and don’t hold their shape

We will look at

- how do they respond to forces?
- how do they respond to things floating in them?
- how do they move?

Pressure



Can of Beans
push!
come on water molecules
let's crush this can!

Pressure

Fluids cannot sustain shear stresses or stretching stresses, only compressive stresses

- compressive stresses are manifested through **pressure**

Pressure varies with depth

This leads to **buoyant forces** and **Archimedes' principle**

> The buoyant force on an object is equal to the weight of fluid displaced.

Example 39.2: 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?

Summary

Topics

Today: Fluid mechanics [chapter 14]

- Pressure
- Archimedes' Principle

Monday: Pascal's law [chapter 14]

- Pascal's law
- Hydraulic lift
- Measuring pressure

PHYSICS 101 - HONORS

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Pressure (slide 4)

What is going on here? Roughly speaking - the can of beans displaces water, causing the water level to rise. Gravity still pulls on the water, and the water "wants" to find the lowest level possible. The water "tries" to force itself back, from all directions, into the volume occupied by the can. Water pressure causes a force that pushes into the can from all directions. That pressure depends on depth.

Pressure is defined as

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

← F perpendicular to the surface exerted by a static fluid

↑ P scalar!

If F not constant

$$P = \frac{dF}{dA}$$

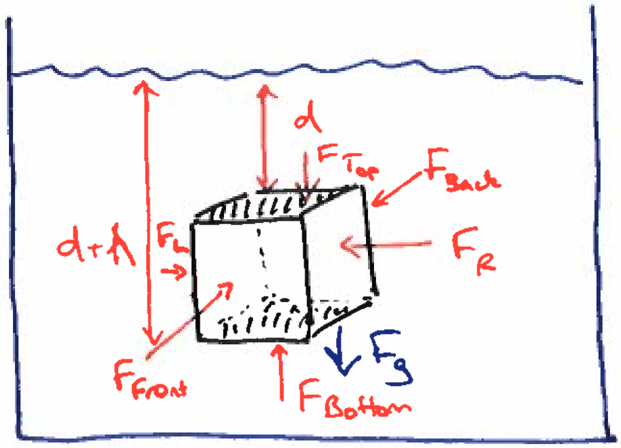
units are $\frac{N}{m^2}$ or Pascals (Pa)

Atmospheric pressure is $1 \text{ atm} \equiv 101{,}325 \text{ Pa}$

$\simeq 10^5 \text{ Pa}$

Pressure varies with depth!

Consider a small volume of fluid within a larger volume



Assume fluid is <u>incompressible</u>
- volume doesn't change
- density uniform throughout fluid

Let's look at the forces; assuming fluid is in equilibrium

Newton II $\Rightarrow$ $\sum \vec{F} = 0$

Vertically: $-F_{Top} + F_{Bottom} - F_g = 0$

$$-F_{Top} + F_{Bottom} - mg = 0$$

Now divide by area

$$-\frac{F_{Top}}{A} + \frac{F_{Bottom}}{A} - \frac{mg}{A} = 0$$

$\Delta P = P - P_0 = \frac{\text{weight}}{\text{area}}$ of the fluid on top of a given depth h.

$$-P_0 + P - \frac{mg}{A} = 0 \quad \Rightarrow \quad P = \frac{mg}{A} + P_0$$

Remember that the mass is $m = \rho V = \rho (Ah)$

$$\Rightarrow P = P_0 + \rho \frac{Ahg}{A} = P_0 + \rho g h$$

$$\boxed{P = P_0 + \rho g h}$$

$\rho g h$ ← weight of column of fluid

P ↑ pressure at depth h; P_0 ↑ pressure at top

Pressure changes with depth!

Let's think about these vertical forces again

$$\Delta F = F_{Bottom} - F_{Top}$$

$$= P_{Bottom} A - P_{Top} A$$

$$= (P_{Bottom} - P_{Top}) A$$

$$= (P - P_0) A$$

$$= (\rho g h) A$$

$$= \rho g V$$

$$= \rho V \cdot g = M_{fluid}\, g$$

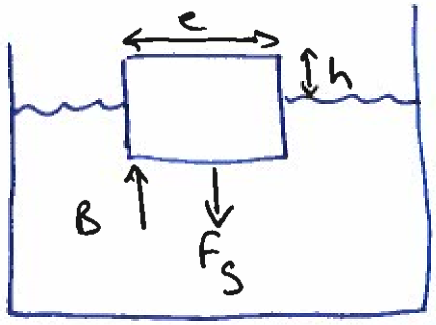
$\Rightarrow$ **Buoyant force = $\rho g \cdot$ volume of liquid displaced = weight displaced**

Fluid exerts a buoyant force equal to the weight of the fluid displaced ← Archimedes' principle

Note

- volume of fluid displaced = volume of object submerged
- weight of fluid displaced ≠ weight of object (not necessarily, anyway)

Cube example (slide 8)



In equilibrium $\Rightarrow \Sigma \vec{F} = 0$

Vertically $\Rightarrow \vec{B} + \vec{F_g} = 0$

or $B - mg = 0$

(m_{cube}!)

B = weight of water displaced.

$= M_{H_2O}\, g$

$= \rho_{H_2O} V_{H_2O}\, g$

$= \rho_{H_2O} \cdot e^2(e-h) \cdot g$

$V_{H_2O} = e \cdot e \cdot (e-h)$
$= e^2(e-h)$

$\Rightarrow \rho_{H_2O}\, e^2(e-h)\, g = M_{cube}\, g$

$\rho_{H_2O}\, e^2(e-h)\, g = \rho_{cube} V_{cube}\, g$

$\rho_{H_2O}\, e^2(e-h)\, g = \rho_{cube}\, e^3\, g$

$\Rightarrow \quad e - h = \dfrac{\rho_{cube}\, e^3\, g}{\rho_{H_2O}\, e^2\, g}$

$= \dfrac{\rho_{cube}}{\rho_{H_2O}}\, e$

$\Rightarrow \quad h = e - \dfrac{\rho_{cube}}{\rho_{H_2O}}\, e = e\left(1 - \dfrac{\rho_{cube}}{\rho_{H_2O}}\right)$

$= 0.2 \cdot \left(1 - \dfrac{650}{1000}\right) \simeq 0.07\ m$

or $\boxed{h = 7\ cm}$