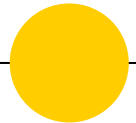


Physics 101H

General Physics 1 - Honors



Lecture 37 - 11/10/22

Pressure



Summary

Topics

Monday: Noether's theorem

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

Today: Fluid mechanics [chapter 14]

- Pressure
- Archimedes' Principle

Announcements

Yesterday:

Problem set 7 posted

Fluids



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

- point particles
- rigid extended objects
- deformable extended objects

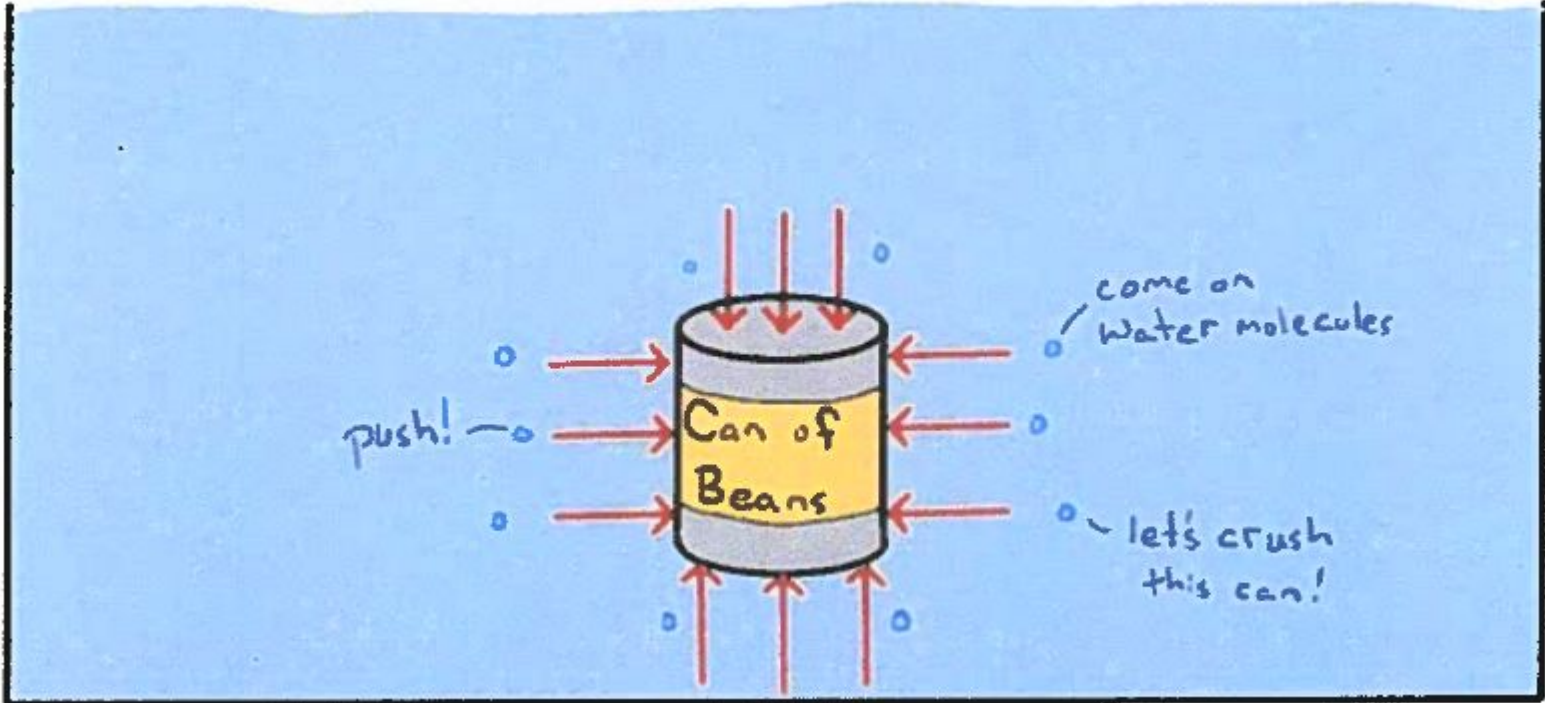
Today we switch our attention to **fluids**

- 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



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.

Question: Which weighs more, pepsi or diet pepsi?

Question: Which weighs more, pepsi or diet pepsi?



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?



Summary

Topics

Today: Fluid mechanics [chapter 14]

- Pressure
- Archimedes' Principle

Tomorrow: Pascal's law [chapter 14]

- Pascal's law
- Hydraulic lift
- Measuring pressure

Announcements

Wednesday:

Problem Set 7 posted

PHYSICS 101 - HONORS

Lecture 37 11/10/22

Pressure (slide 4)

What is going on here? Roughly speaking - the car of bears 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 car.

Water pressure causes a force that pushes into the car from all directions. That pressure depends on depth.

Pressure is defined as

$$P = \frac{F}{A} \leftarrow \begin{array}{l} \text{perpendicular to the surface} \\ \text{exerted by a static fluid} \end{array}$$

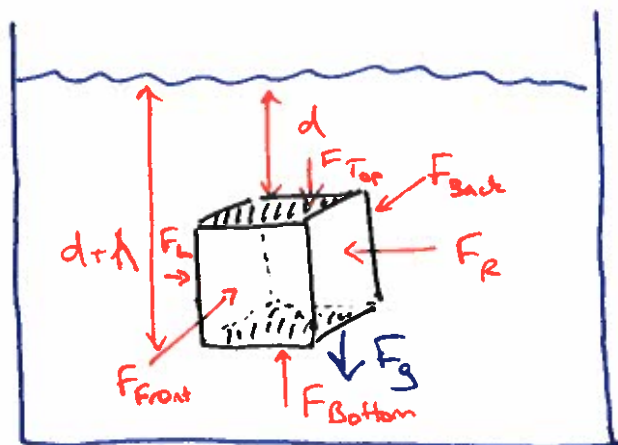
$$\text{If } F \text{ not constant} \\ P = \frac{dF}{dA}$$

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

Atmospheric pressure is $1 \text{ atm} \equiv 101,325 \text{ Pa}$
 $\approx 10^5 \text{ Pa}$

Pressure varies with depth!

Consider a small volume of fluid within a larger volume



Assume fluid is incompressible

- volume doesn't change
- density uniform throughout fluid

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

$$\text{Newton II} \Rightarrow \Sigma \vec{F} = 0$$

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

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

Now divide by area

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

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

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

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

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

$$P = P_0 + \rho gh$$

weight of column of fluid

Pressure changes with depth!

↑ pressure at depth. ↑ pressure at top

Let's think about these vertical forces again

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

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

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

$$= (P - P_0) A$$

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

$$= \rho g V \quad \Rightarrow$$

$$= \rho V \cdot g = m_{\text{fluid}} g$$

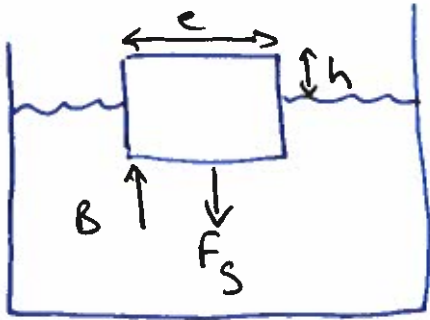
$$\text{Buoyant force} = \rho g \cdot \text{volume of liquid displaced} \\ = \text{weight displaced}$$

Fluid exerts a buoyant force equal to the weight of the fluid displaced

Note

- volume of fluid displaced = volume of object submerged
- weight of fluid displaced \neq weight of object (necessarily, ^{not} anyway)

Cube example (slide 8)



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

Vertically $\Rightarrow \vec{B} + \vec{F}_g = 0$

$$\text{or } B - mg = 0$$

(cube!)

$B =$ weight of water displaced.

$$= M_{H_2O} g$$

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

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

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

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

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

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

$$\Rightarrow e-h = \frac{\rho_{\text{cube}} e^3 g}{\rho_{H_2O} e^2 g}$$

$$= \frac{\rho_{\text{cube}} e}{\rho_{H_2O}}$$

$$\Rightarrow h = e - \frac{\rho_{\text{cube}} e}{\rho_{H_2O}} = e \left(1 - \frac{\rho_{\text{cube}}}{\rho_{H_2O}} \right)$$

$$= 0.2 \cdot \left(1 - \frac{650}{1000} \right) \approx 0.07 \text{ m}$$

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