Density, Pressure, and Buoyancy

Test #3 is in two weeks!

- April 12, 7-10pm, Eisland G24 as usual. Please let me know by April 5 if you need a make-up exam.
- Covers Chapters 7-10.
  - For gravity section, will only test gravitational force, not escape velocity and altitude-dependent GPE.
  - Practice tests and equation sheet are on my website: https://sarahspolar.faculty.wvu.edu/classes/physics-101-fall-2018
  - If you’re happy with test 1 and 2 scores, you can skip test 3!

Why does ice float?

And penguins, now that we’re talking about it.

Density clicker trial.

You have a 114.6 kg cube of ice that measures 0.5 x 0.5 x 0.5 meters. What is the density of ice?

A. 114.6 kg
B. 229.2 kg/m²
C. 458.4 kg/m³
D. 916.8 kg/m³
Density.

You have a 114.6 kg cube of ice that measures 0.5 x 0.5 x 0.5 meters. What is the density of ice?

\[ \rho = \frac{M}{V} = \frac{\text{mass}}{\text{volume}} \]

This greek letter is called "rho".

The sphere on the right has twice the mass and twice the radius of the sphere on the left. Compared to the sphere on the left, the larger sphere on the right has:

A. twice the density.
B. the same density.
C. 1/2 the density.
D. 1/4 the density.
E. 1/8 the density.

\[ V_{\text{sphere}} = \frac{4}{3} \pi r^3 \]

\[ \rho = \frac{M}{V} = \frac{\text{mass}}{\text{volume}} \]

Why does ice float?

• Why is the surface of water always flat?
• Why is sea level the same everywhere?
• Why does oil float on water?
• Why does ANYTHING float?!!

What happens when pressure is uneven?
Hydrostatic equilibrium
If forces are BALANCED, fluid or gas is not moving.

\[ P = P_0 + \rho gh \]

Implications:
Pressure of liquid varies with depth because of gravity.
Holds things of a given density at a certain height in a liquid (keeps them floating)!

Hydrostatic equilibrium: The forces behind the magic.

\[ P = P_0 + \rho gh \]

Earth atmospheric pressure at sea level:
\[ P_0 = 1.01 \times 10^6 \text{ Pa} \]

Assume:
All the fluid has the same density.
Fluid is not moving around.

You dive into a lake and start to swim toward the bottom. You feel increasing pressure on your ears as you swim down, and so quickly calculate what depth you can get to before your eardrums will rupture. Eardrums usually rupture at over-pressures above ~50 kPa. How deep can you swim before this happens? [area of eardrum ~ 1 cm²]

\[ P = P_0 + \rho gh \]

Earth atmospheric pressure at sea level:
\[ P_0 = 1.01 \times 10^6 \text{ Pa} \]

Density of water: 1000 kg/m³

Note
less dense liquid

\[ P_{\text{air}} = P_{\text{black}} \]

At boundaries of different materials, the pressure of the fluids/gases is matched to adjacent one.

more dense liquid

\[ P_{\text{black}} = P_{\text{sun}} \]
Let's say you throw a weight in a tub. How much water will it displace? Will it sink or float? What makes it float?

“Buoyant force”
\[ F_b = W_{\text{Fluid Displaced}} \]
weight of displaced fluid

**Archimedes’ Principle**

Any object completely or partially submerged in a fluid is buoyed up by a force equal to the weight of the fluid displaced.

“Buoyant force”
\[ F_b = W_{\text{Fluid Displaced}} \]
\[ F_b = M_{\text{Water Displaced}} \rho_{\text{Fluid}} g V \]

**Totally submerged object**

If the density of the fluid is greater than the density of the object, the object floats!
Two blocks (A and B) have the same size and shape. Block A floats in the water, but Block B sinks in the same water. Which block has the larger buoyant force on it?

\[ F_b = W_{FluidDisplaced} \]

A. Block A has the larger buoyant force on it.
B. Block B has the larger buoyant force on it.
C. Neither; they have the same.
D. Not enough information

Ice and penguins have a net buoyant force upward.

\[ \rho_{water} = 1000 \text{ kg/m}^3 \]
\[ \rho_{ice} = 916.8 \text{ kg/m}^3 \]

How can a steel ship float?

The hull contains mostly air and displaces a lot of water... enough so that \( F_b = F_g \) and it floats.
Why does ice float?

- Why is the surface of water always flat?  
  (equal pressure at a given height)

- Why is sea level the same everywhere?  
  (equal pressure at a given height)

- Why does oil float on water?  
  (it's less dense)

- Why does ANYTHING float?!?  
  (it's less dense)