**Agenda**
- Today: Finish wave interference, start pressure and density
- Wednesday: Midterm #3! No reading today.
- Friday: More fluids: buoyancy and Archimedes' principle
- Reading after the exam: CH 16

**Density**
- **Definition of Density**, $\rho$
- $\rho = M/V$
- SI unit: kg/m$^3$
- The densities of most liquids and solids vary only slightly with changes in temperature and pressure
- Densities of gases vary greatly with changes in temperature and pressure

**Pressure**
- Pressure is force per unit area
- **Definition of Pressure**, $P$
- $P = F/A$
- SI unit: N/m$^2$
- 1 N/m$^2$ = 1 Pascal (Pa)
- Other common pressure units:
  - Pounds per Square inch (PSI) - tires, etc.
  - mm Hg - blood pressure
  - inches Hg - weather barometer

**Pressure changes with Contact Area**
The same force applied over a smaller area results in greater pressure – think of poking a balloon with your finger and then with a needle.

**Conceptual Check**
In which case is the pressure greatest?

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### Pressure in Liquids
- Consider forces on a small amount of liquid in terms of pressure
- \( P_f = \rho gd + P_0 \)
- Similarly to \( PE_{gr} \), we mostly only care about pressure differences.
- Atmospheric pressure (at sea level) = 101.3 kPa

### Buoyancy
- Pressure depends on depth.
- Consider a large rock: The bottom of the rock is at a lower depth, so it feels more pressure than the top of the rock.
- This net upward force is called buoyancy.

### Displacement of Liquid
- Objects displace a volume of liquid equal to their volume
- This is useful for determining irregular or odd volumes

### Helpful to know:
- Properties of water:
  - 1 kg of liquid water takes up 1 L of volume
  - 1 kg of water weighs 10 N.
  - Water has a mass density of 1 g/cm\(^3\), or 1000 kg/m\(^3\)
- What would it take for the buoyant force to be greater than the weight of the object displacing some volume of water?

### Archimedes’ Principle
The buoyant force on an immersed object is equal to the weight of the fluid it displaces.

\[
F_B = m_f g = \rho_f V_f g
\]
- Note: Buoyant force does NOT depend on depth!

### Will it float?
Any object immersed in a liquid will feel a buoyant force, but that doesn’t mean it will float.
1. An object more dense than the fluid in which it is immersed will sink.
2. An object less dense than the fluid in which it is immersed will float.
Archimedes’ Principle (Again)

- Applies for air as well as water!
- An object surrounded by air is buoyed up by a force equal to the weight of the air displaced.
- 1 m³ of air has a mass of about 1.2 kg, whereas 1 m³ of water has a mass of 1000 kg!
- Buoyant force due to air is usually very small

Which object feels the largest buoyant force due to the atmosphere?

A. An elephant
B. A helium-filled party balloon
C. A skydiver at terminal velocity

Agenda

- Today: More Fluids
- Monday: Finish fluids, begin thermodynamics
- Reading: Finish CH 16, start CH 17

More Floating

- Remember Archimedes’ Principle: An immersed object feels a buoyant force equal to the weight of the fluid it displaces.
- Objects with density less than the fluid will float.
- How do modern ships float???

Using a spring scale, you measure the weight of a box to be 30 N. When you dip the box into four unknown liquids, you get the following readings on the spring scale:

Liquid A: 22 N
Liquid B: 10 N
Liquid C: 28 N
Liquid D: 0 N

Which liquid is the most dense? Which is least dense? How do you know?
Floating Depends on Average Density

- Imagine a solid block of iron, and a sheet of iron bent into a boat-like shape.
- We have increased the effective volume of the sheet of iron.
- This lowers its average density, allowing it to float.

A floating object displaces a weight of fluid equal to its own weight.

Atmospheric Pressure

- Density of air in the atmosphere decreases with increasing altitude.
- Most of atmosphere in the first 10 km (about 6 miles) of altitude.

Pascal’s Principle

“A change in pressure at any point in an enclosed fluid is transmitted undiminished to all points in the fluid.”

Pascal’s Principle: Example

- Remember, Pressure = force / area.
- Pressure on both pistons is the same (due to Pascal’s Principle).
- Imagine the area of the small piston is 1 m$^2$, and the area of the large piston is 5 m$^2$.
- What force acts on the large piston?

Continuity and Fluid Flow

Imagine water flowing through a pipe that goes from wide to narrow: speed of water increases through narrow portion of the pipe. (what goes in must come out)

$$A_1v_1 = A_2v_2$$

A = cross-sectional area of pipe
v = velocity

Bernoulli’s Principle

“Where the speed of a fluid increases, internal pressure in the fluid decreases.”

- Additional way to change the pressure in a liquid (other was depth).
**Bernoulli’s Principle**

- If speed of a fluid increases, the pressure in the fluid decreases.
- This phenomenon is due to energy conservation; when fluid’s KE increases (velocity increases) its internal P (pressure) decreases.

**Bernoulli’s Equation**

\[
P_1 + \frac{1}{2} \rho v_1^2 + \rho gh_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho gh_2
\]

Bernoulli’s equation comes from conservation of energy: P term comes from work done on a fluid, \( \frac{1}{2} \rho v \) term comes from kinetic energy, and \( \rho gh \) term comes from gravitational potential energy.

**Archimedes’ Principle Example**

A piece of wood is tied to a string inside a tub filled with water. The string is attached to the bottom of the tub, and the wood is completely submerged. If the wood has a volume of 8 cm\(^3\) and a density of 600 kg/m\(^3\), what is the tension in the string?

**Bernoulli’s Equation Example**

The buildup of plaque on the walls of an artery may decrease its diameter from 1.1 cm to 0.75 cm. If the speed of the blood flow was 15 cm/s before reaching the region of plaque buildup, find:

a) The speed of blood flow  
b) The pressure drop within the plaque region.

Water is flowing continuously in the pipe from point A to point C. Rank the three points in terms of the internal pressure from biggest to smallest.