Physics 101: Lecture 18
Fluids: Statics

EXAM 2

- Exam 2 will be held this Wed 10/31 – Fri 11/2
- You MUST sign up for a time slot here:

https://cbtf.engr.illinois.edu

- Review tonight in Loomis 151, 6PM
  - I will go over Exam 2 from Fall 2005 (bring with you)
- Exam covers Lectures 9-16:
- No lab on week of exam (good sign-up slot!)
- Discussion **IS** held the week of the exam
- Contact Dr. Schulte w/ sign up Qs: eschulte@illinois.edu

Big Ideas in Physics 101

- $F_{Net} = m\,a = \Delta p/\Delta t$ (Newton's Second Law)
- $F_{Net}\Delta x = W = \Delta K$ (Work-Kinetic energy theorem)
- $F_{Net}\Delta t = I_{mpulse} = \Delta p$ (Impulse-momentum theorem)
- $\tau_{Net} = I\,\alpha = \Delta L/\Delta t$ (N#2 for rotation)
- $\tau_{Net}\,\Delta t = \Delta L$ (Angular impulse - ang. mom. thm)
- Today: We apply these ideas to molecules in fluids!
  ➔(All remaining lectures are applications of the 4 big ideas)

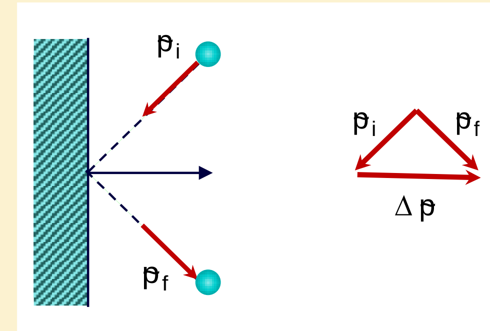
States of Matter

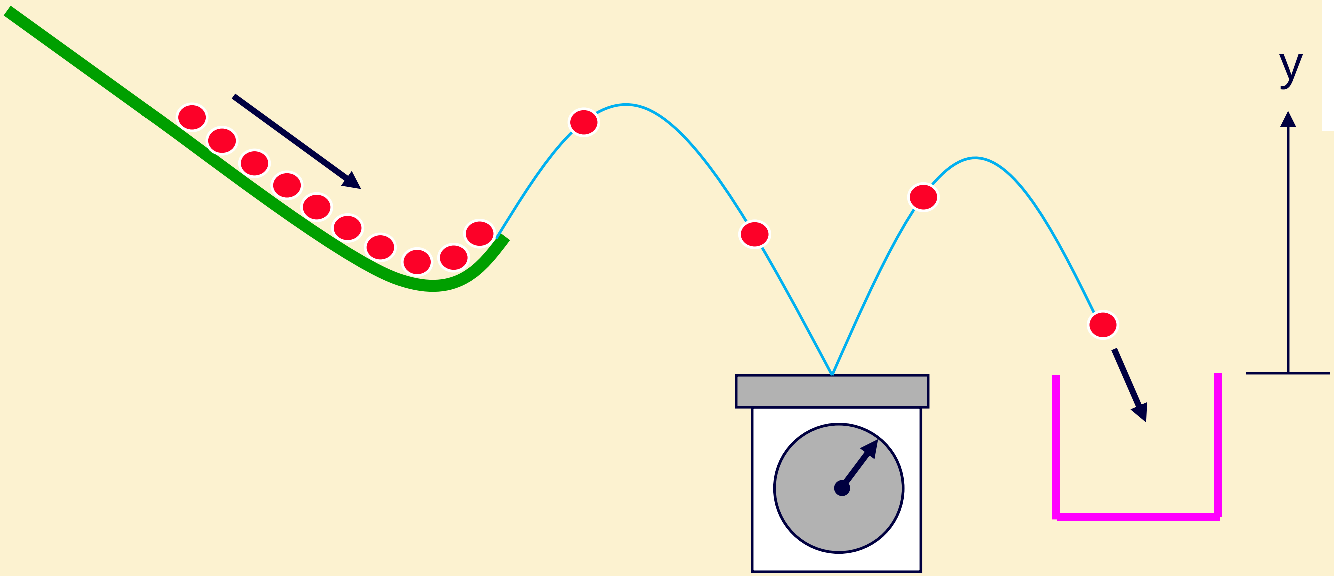
- Solid
  - Hold Volume
  - Hold Shape
- Liquid
  - Hold Volume
  - Adapt Shape
- Gas
  - Adapt Volume
  - Adapt Shape

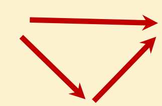
Fluids

Qualitative Demonstration of Pressure

- Force due to molecules of fluid colliding with container.
  - ➔ Impulse $F_{av}\, \Delta t = \Delta p$
- Average $\boxed{\text{Pressure} = F / A}$







$$\text{Average vertical force} = \langle f_y \rangle = \frac{\Delta p_y}{\Delta t} = \frac{\Delta(m v_y)}{\Delta t}$$

Atmospheric Pressure

- Basically weight of atmosphere
- Air molecules are colliding with you now
- Pressure = 1×10^5 N/m^2 = 14.7 lbs/in^2
- Example: Sphere with r = 0.1 m
  - ➔ Magdeburg Spheres demo

    $A = 4 \pi r^2 = .125 \text{ m}^2$

    F = 12,000 Newtons (over 2,500 lbs)!

Can demo

Checkpoint 3

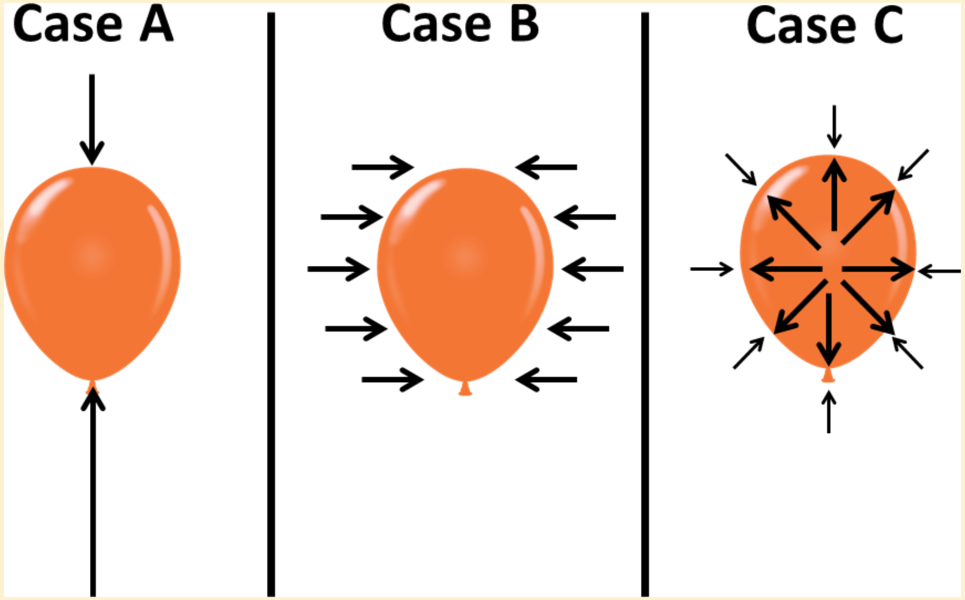
On a sunny day with no wind, you fill a balloon with helium and let it float away into the sky. Eventually, the balloon pops.

This is because at high elevation,

Case A: The net pressure acting upward and downward on the balloon squeezes it until it bursts.

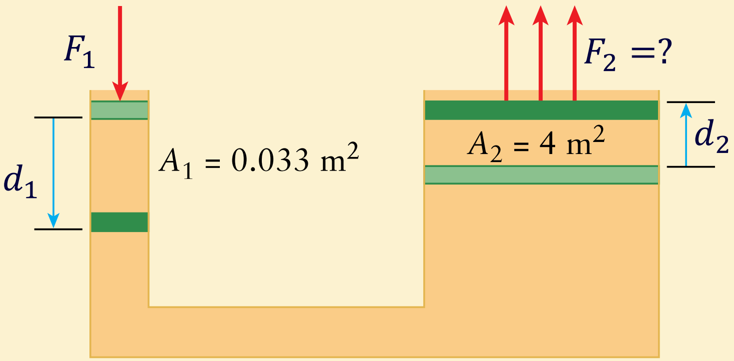
Case B: The net lateral pressure squeezes the balloon until it bursts.

Case C: The pressure inside the balloon is greater than the pressure outside the balloon, causing the balloon to expand until it bursts.



Pascal's Principle

- A change in pressure at any point in a confined fluid is transmitted everywhere equally in the fluid.
- Hydraulic Lift



$\Delta P_1 = \Delta P_2$

$F_1/A_1 = F_2 / A_2$

$F_1 = F_2 (A_1/A_2)$

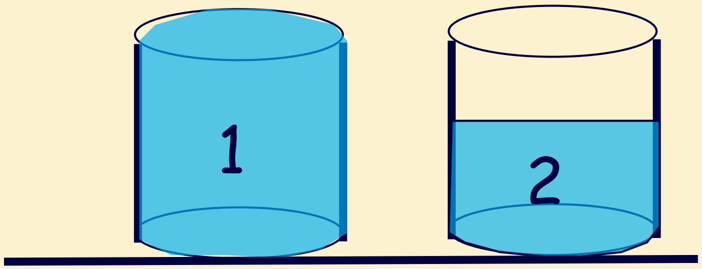
lift demo

- Compare the work done by F_1 with the work done by F_2

A) $W_1 > W_2$ B) $W_1 = W_2$ C) $W_1 < W_2$

Gravity and Pressure Clicker Q

- Two identical “light” containers are filled with water. The first is completely full of water, the second container is filled only ½ way. Compare the pressure each container exerts on the table.



A) $P_1 > P_2$ B) $P_1 = P_2$ C) $P_1 < P_2$

Pascal's Principle (Restated)

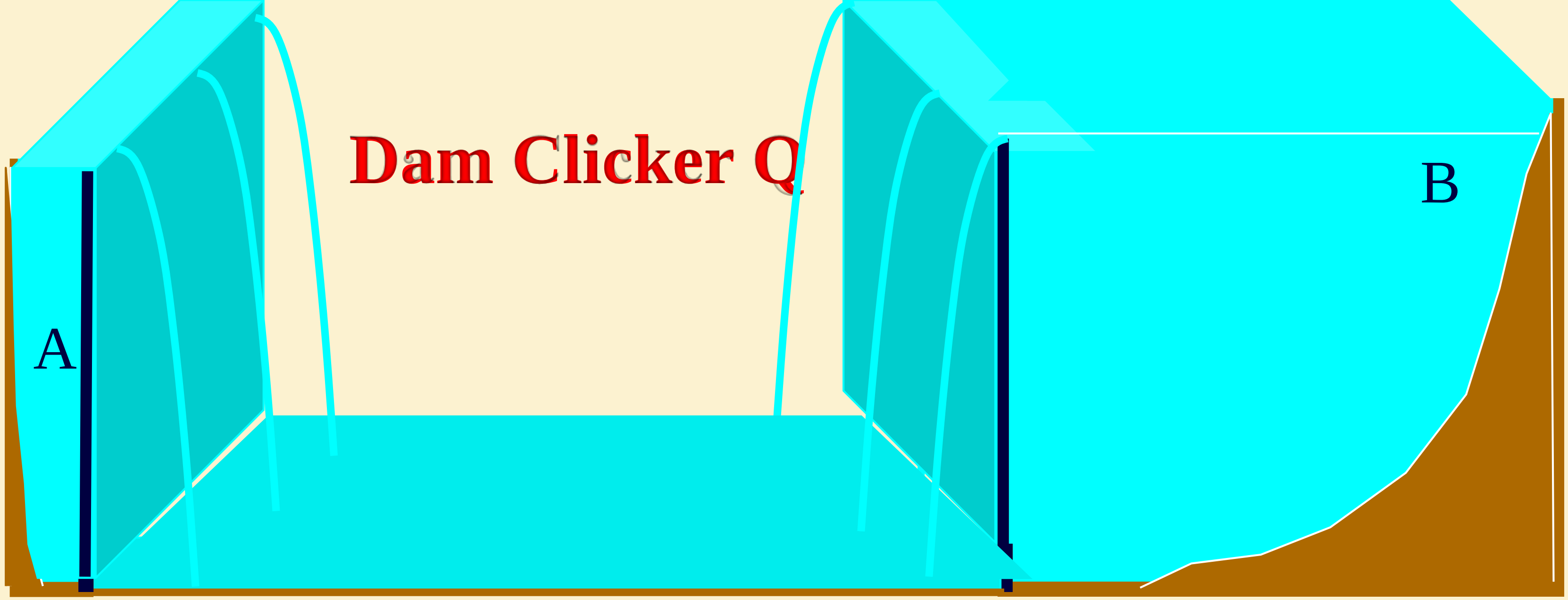
1. Without gravity: Pressure of a confined fluid is everywhere the same.

2. With gravity: $P = P_{atm} + \rho g h$

Density of fluid: $\rho = M/V$

Pressure of a fluid is everywhere the same *at the same depth*.

In general: in a confined fluid, change in pressure is everywhere the same.



Two dams of equal height prevent water from entering the basin. Compare the net force due to the water on the two dams.

A) $F_A > F_B$ B) $F_A = F_B$ C) $F_A < F_B$

Checkpoint 2

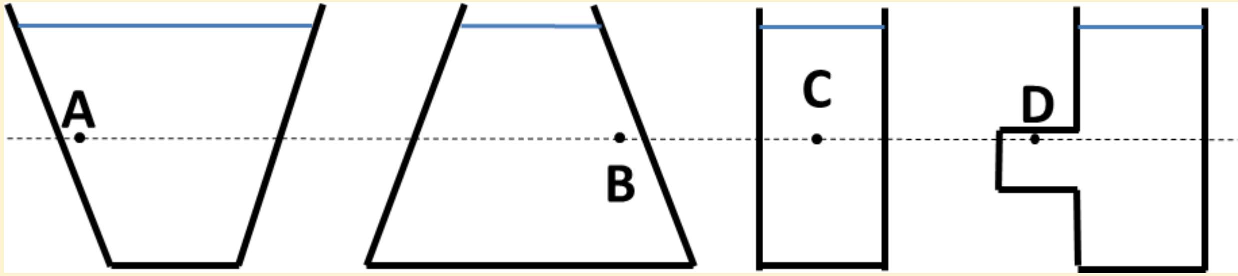
The containers shown in the figure each have a different shape but are filled to the same height with the same fluid.

Which of the three objects experiences the greatest buoyant force?

Which point is at the lowest pressure?

A B C D

E. All points are at the same pressure



Pressure and Depth

Barometer: a way to measure atmospheric pressure

For **non-moving** fluids, pressure depends only on depth.

$p_2 = p_1 + \rho g h$

$P_{atm} - 0 = \rho g h$

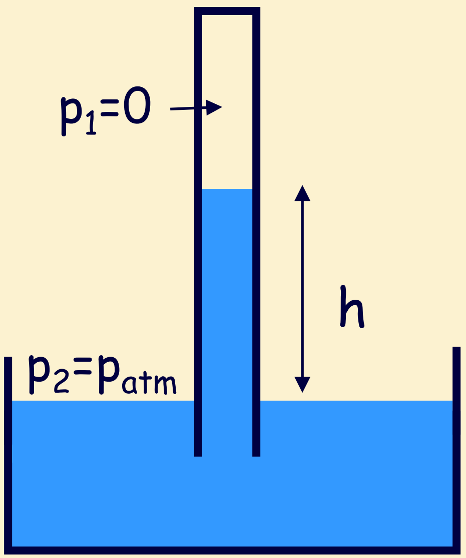
Measure h, determine p_{atm}

example--Mercury

$\rho = 13{,}534\ \mathrm{kg/m^3}$

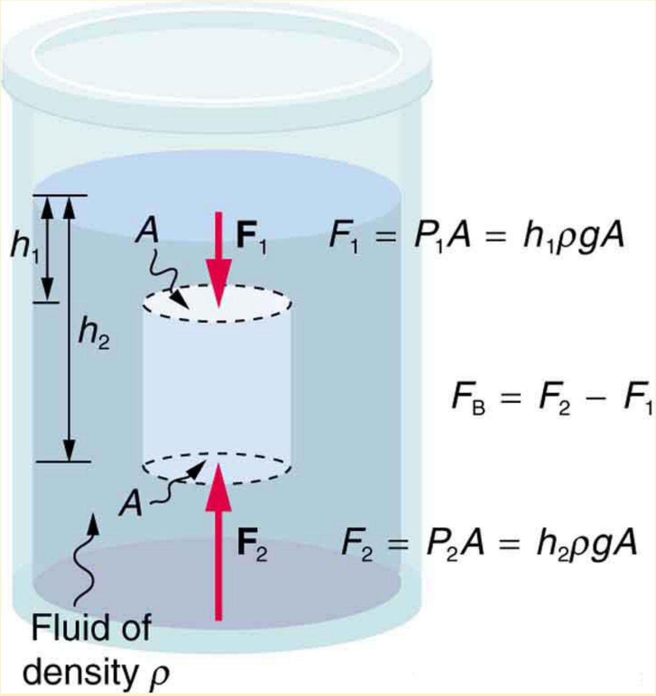
$p_{atm} = 1.013 \times 10^5\ \mathrm{Pa}$

$\Rightarrow h = 0.763\ \mathrm{m} = 763\ \mathrm{mm} = 30''$ (for 1 atm)



Archimedes' Principle

- Determine net force of fluid on immersed cube
  - ➔ Buoyant force is due to fluid
    - » $F_B = F_2 - F_1$
    - » $= P_2\, A - P_1\, A = (P_2 - P_1\,)A$
    - » $= (\rho g h_2 - \rho g h_1)A$
    - » $= \rho\, g\, d\, A$
    - » $= \rho\, g\, V$
    - » $= (M_{fluid}/V)\, g\, V$
    - » $= M_{fluid}\, g$



- Buoyant force is weight of displaced fluid!

Checkpoint 1

Three objects made of common biomaterials have the same volume but different shapes. The objects are submerged in fresh water and hang attached by a lightweight string.

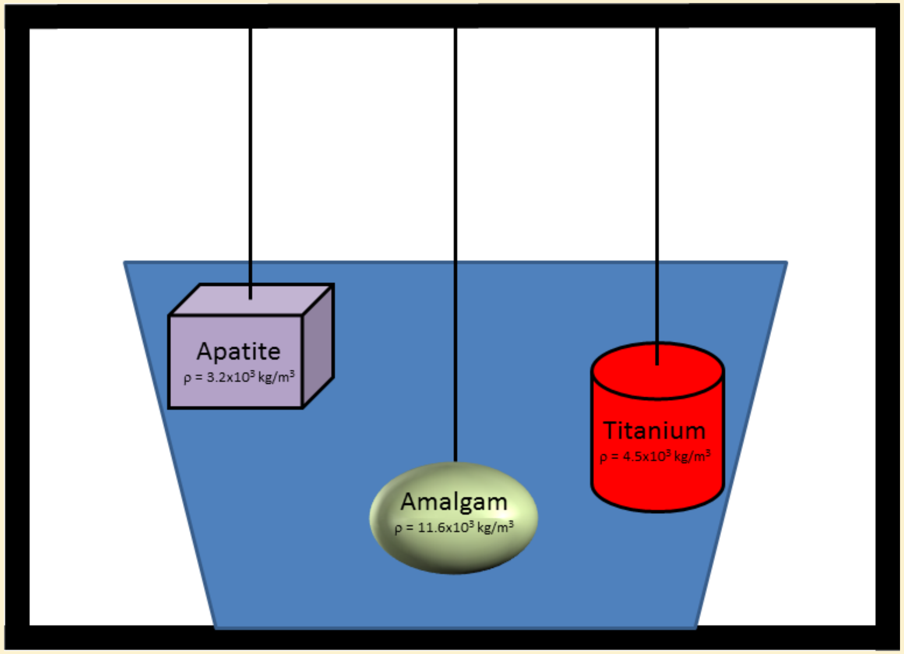
Which of the three objects experiences the greatest buoyant force?

A) The object made of apatite

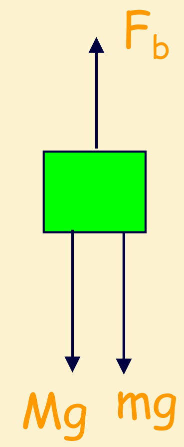
B) The object made of amalgam

C) The object made of titanium

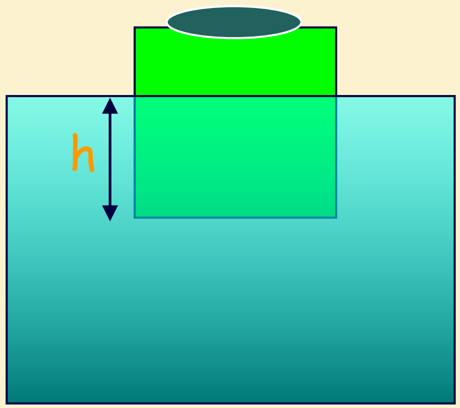
D) All the same



Archimedes Example



A cube of plastic 4.0 cm on a side with density = 0.8 g/cm^3 is floating in the water. When a 9 gram coin is placed on the block, how much does it sink below the water surface?



$M = \rho_{plastic} V_{cube}$

$= 4 \times 4 \times 4 \times 0.8$

$= 51.2$ g

$F_{Net} = m\,a = 0$

$F_b - Mg - mg = 0$

$\rho\, g\, V_{disp} = (M+m)\, g$

$V_{disp} = (M+m) / \rho$

$h\, A = (M+m) / \rho$

$h = (M + m)/ (\rho\, A)$

$= (51.2+9)/(1 \times 4 \times 4) = 3.76$ cm [coke demo]

Summary

- Pressure is force exerted by molecules "bouncing" off container $P = F/A$

- Gravity/weight affects pressure

  ➔ $P = P_0 + \rho g d$

- Buoyant force is "weight" of displaced fluid. $F = \rho g V$