Physics 101: Lecture 18
Fluids: Statics

EXAM 2

- Exam 2 will be held Wed 3/28 – Fri 3/30
- You MUST sign up for a time slot before noon tomorrow:

https://my.physics.illinois.edu/undergrad/onlineexams/signup-student.asp

- Exam is computer-administered in Loomis 257
- Exam covers Lectures 9-15 (Work & Energy through Torque and equilibrium)
- No lab the week of exam (good sign-up slot!)
- Discussion **IS** held the week of the exam
- Contact Dr. Schulte w/ Qs about sign up: eschulte@illinois.edu
- Exam is all multiple choice (3 & 5 choice Qs)
- Study using old exams!

Overview of Big Ideas in course

- $F_{Net} = m\,a = \Delta p/\Delta t$ (Newton's Second Law)
- $F_{Net}\Delta x = \Delta K$ (Work-Kinetic energy thm)
- $F_{Net}\Delta t = \Delta p$ (Impulse-momentum thm)
- $\tau_{Net} = I\,\alpha = \Delta L/\Delta t$ (N#2 for rotation)
- $\tau_{Net}\,\Delta t = \Delta L$ (Angular impulse - ang. mom. thm)
- Today: We apply these ideas to molecules in fluids! {Medium to Small ideas}

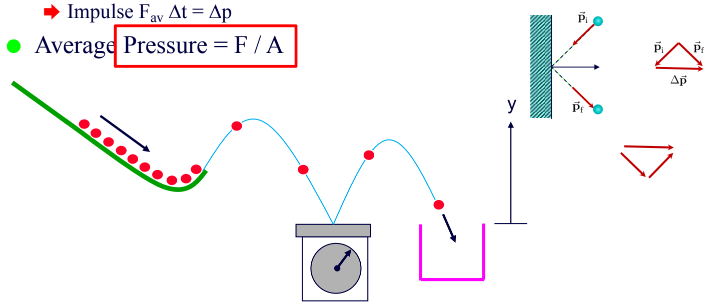
States of Matter

- 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 Pressure = F / A



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 right now!
- Pressure = $1\text{x}10^5$ N/m^2 = 14.7 lbs/in^2!
- Example: Sphere with r = 0.1 m
  - Magdeburg Spheres demo

A = 4 π r^2 = .125 m^2

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

Can demo

Pascal's Principle

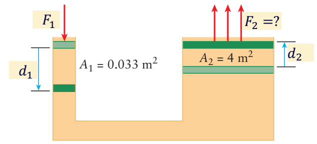
- A change in pressure at any point in a confined fluid is transmitted everywhere equally in the fluid.
- Hydraulic Lift

  $\Delta P_1 = \Delta P_2$

  $F_1/A_1 = F_2 / A_2$

  $F_1 = F_2 (A_1/A_2)$

  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) $W_1 < W_2$

$W = F\, d \cos\theta$ but: $A_1 d_1 = V_1 = V_2 = A_2 d_2$

$W_1 = F_1 d_1$ Substitute $(A_1 / A_2) d_1 = d_2$

$= F_2 (A_1 / A_2)\, d_1 = F_2 d_2 = W_2$

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.

Pressure and Depth

Barometer: a way to measure atmospheric pressure

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

$p_2 = p_1 + \rho g h$

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

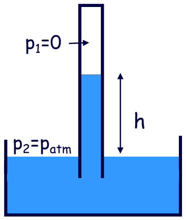
Measure h, determine p_{atm}

example--Mercury

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

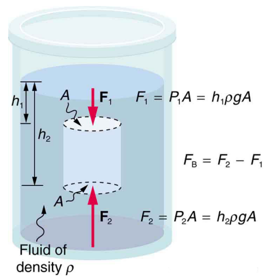
$p_{atm} = 1.013 \times 10^5\ Pa$

$\Rightarrow$ h = 0.763 m = 763 mm = 30" (for 1 atm)



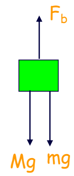
Archimedes' Principle

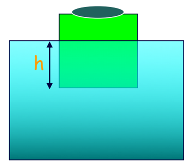
- Determine net force of fluid on immersed cube
  - Buoyant force is due to fluid
    - $F_B = F_2 - F_1$
    - $= P_2 A - P_1 A = (P_2 - P_1)A$
    - $= (\rho g h_2 - \rho g h_1)A$
    - $= \rho\ g\ d\ A$
    - $= \rho\ g\ V$
    - $= (M_{fluid}/V)\ g\ V$
    - $= M_{fluid}\ g$
- Buoyant force is weight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



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?





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

$F_b - Mg - mg = 0$

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

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

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

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

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

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

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

$= 51.2$ g

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. $F = \rho\, g\, V$