Exam III

Physics 101: Lecture 17
Fluids

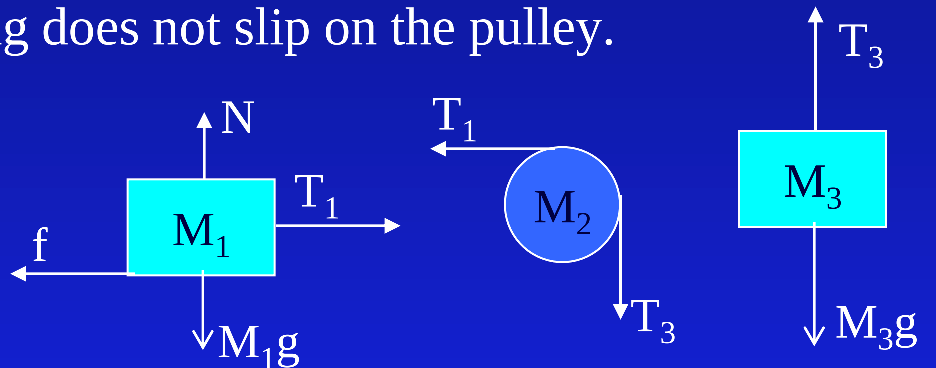
Exam 2 is
Mon April 2, 7pm

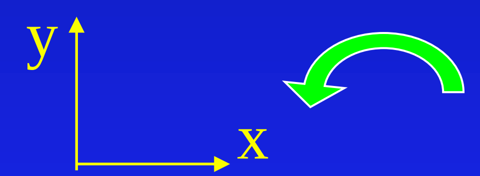
Exam review
(Sun April 1, 3-5 pm
141 Loomis)

Extra office hours on
Friday March 30.

Homework 9 Help

A block of mass **M_1 = 3 kg** rests on a table with which it has a coefficient of friction **μ = 0.73**. A string attached to the block passes over a pulley to a block of mass **M_3 = 5 kg**. The pulley is a uniform disk of mass **M_2 = 0.7 kg** and radius **15 cm**. As the mass **M_3** falls, the string does not slip on the pulley.





Newtons 2[nd] Law

1) $T_1 - f = M_1 a_1$

2) $T_1 R - T_3 R = I\,\alpha_2$

3) $T_3 - M_3\,g = M_3\,a_3$

Notes:

1) $f = \mu\,M_1\,g$

2) $\alpha_2 = -a_1 / R$

3) $I = ½\,M\,R^2$

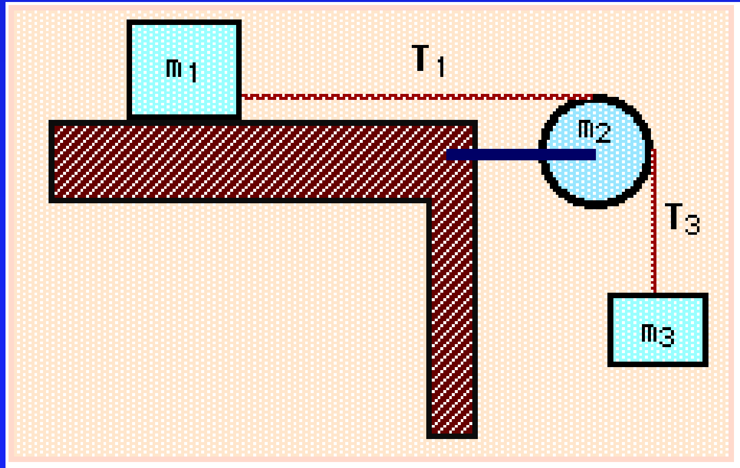
4) $a_1 = -a_3$

Rewrite ($a = a_1$)

1) $T_1 = M_1(a+\mu g)$

2) $T_3 - T_1 = ½\,M_2\,a$

3) $T_3 = M_3\,(g - a)$



Overview

- $\Sigma F = m\,a$
- $\Sigma F \Delta x$ = Change in Kinetic Energy
- $\Sigma F \Delta t$ = Change in momentum
- $\Sigma \tau = I\,\alpha$
- Today: apply these ideas to molecules in fluids

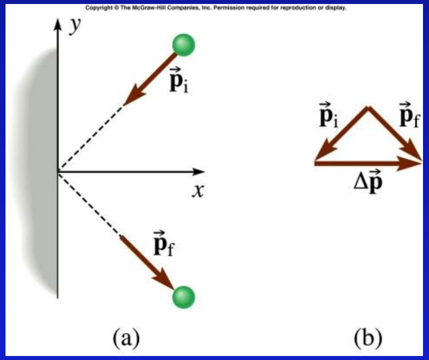
States of Matter

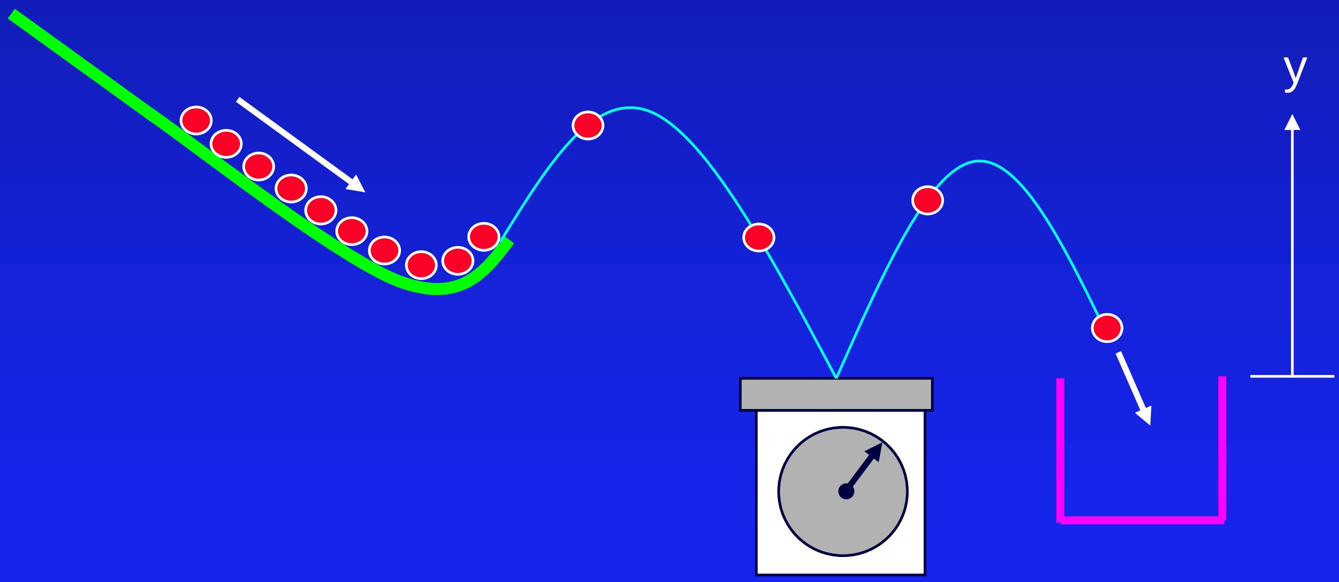
- Solid
  - ➔ Hold Volume
  - ➔ Hold Shape
- Liquid
  - ➔ Hold Volume
  - ➔ Adapt Shape
- Gas
  - ➔ Adapt Volume
  - ➔ Adapt Shape

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





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

Atmospheric Pressure

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

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

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

Can demo

Pascal's Principle

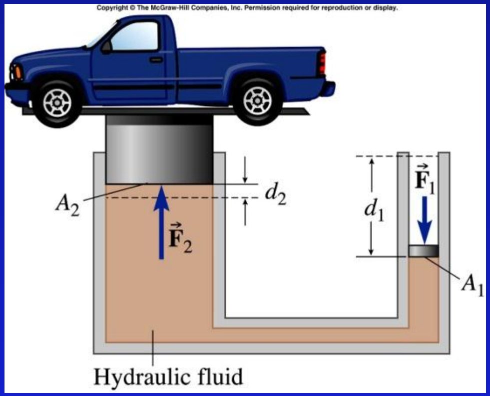
- A change in pressure at any point in a confined fluid is transmitted everywhere in the fluid.
- Hydraulic Lift

  $\Delta P_1 = \Delta P_2$

  $F_1/A_1 = F_2 / A_2$

  $F_1 = F_2 (A_1/A_2)$

  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) $W_1 < W_2$

$W = F\, d \cos\theta$

$W_1 = F_1\, d_1$

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

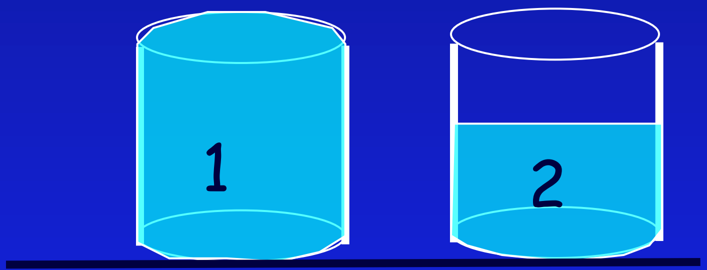
but: $A_1 d_1 = V_1 = V_2 = A_2 d_2$

$= F_2 V_1 / A_2$

$= F_2 d_2 = W_2$

Gravity and Pressure

- 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) $P_1 < P_2$

$P = F/A$

$= mg / A$

Cup 1 has greater mass, but same area

- Under water $P = P_{atmosphere} + \rho g h$

Pascal's Principle (Restated)

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

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

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

Pressure of a fluid is everywhere the same *at the same depth*. [vases demo]

Dam ACT

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

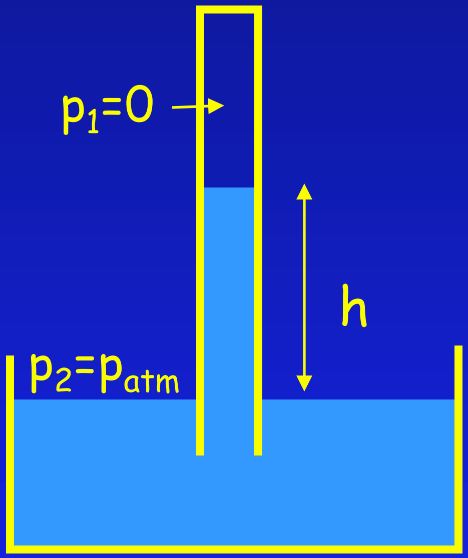
A) $F_A > F_B$ B) $F_A = F_B$ C) $F_A < F_B$

F = P A, and pressure is ρgh. Same pressure, same area same force even though more water in B!

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

$\rho = 13{,}600\ kg/m^3$

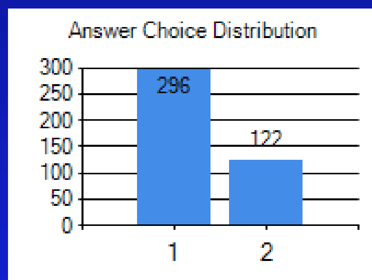
$p_{atm} = 1.05 \times 10^5\ Pa$

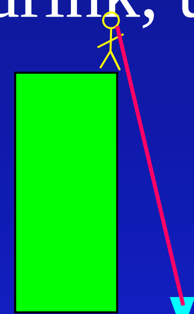
$\Rightarrow h = P_{atm}/\rho/g = 0.757\ m = 757\ mm = 29.80''$ (for 1 atm)

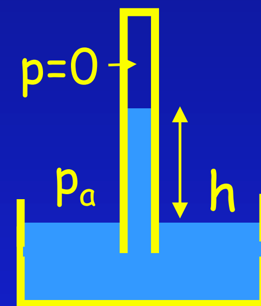
Checkpoint

Is it possible to stand on the roof of a five story (50 foot) tall house and drink, using a straw, from a glass on the ground?

1. No
2. Yes







$$P_a = \rho g h$$

$$h = \frac{P_a}{\rho g}$$

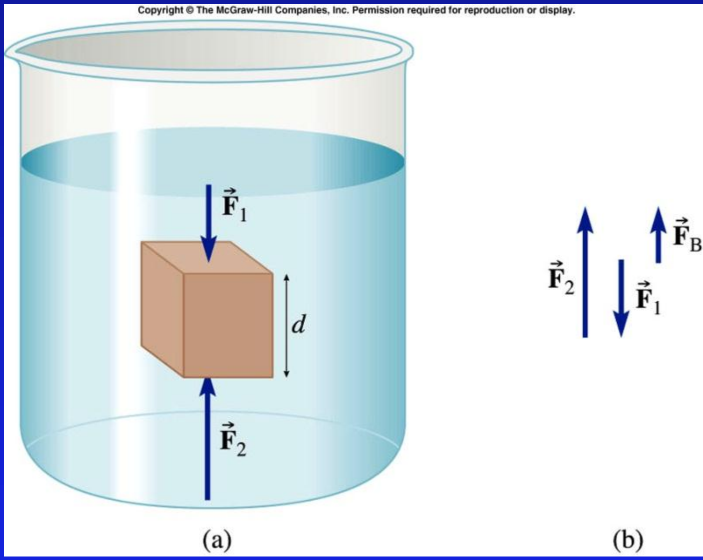
$$= \frac{105000}{1000 \cdot 9.8} = 10.7\,m$$

The atmospheric pressure applied to the liquid will only be able to lift the liquid to a limited height no matter how hard you suck on the straw.

Certainly trees have developed some mechanism to transport water from ground level, through their vascular tissues, and to their leaves (which can be higher that 50 feet)

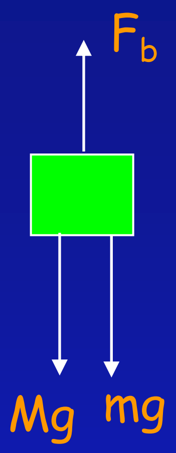
Archimedes' Principle

- Determine force of fluid on immersed cube
  - ➔Draw FBD
    - » $F_B = F_2 - F_1$
    - » $= P_2 A - P_1 A$
    - » $= (P_2 - P_1)A$
    - » $= \rho g d A$
    - » $= \rho g V$

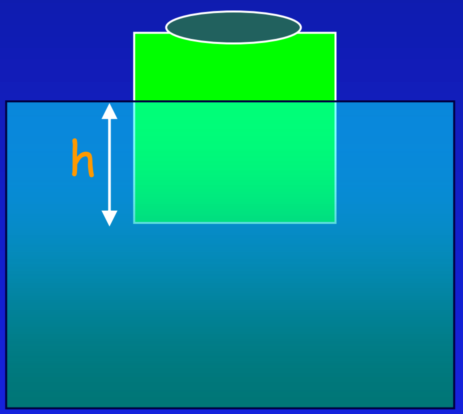


- Buoyant force is weight of displaced fluid!

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?



$\Sigma F = m a$

$F_b - Mg - mg = 0$

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

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

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

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

$= (51.2+9)/(1 \times 4 \times 4) = 3.76$ 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. $F = \rho\ g\ V$