

Announcements – Oct 31, 2013

1. Exam 3 ends Monday 2 pm; late fee after 2 pm Saturday
2. No homework due tonight

3. Happy Halloween!

Pressure

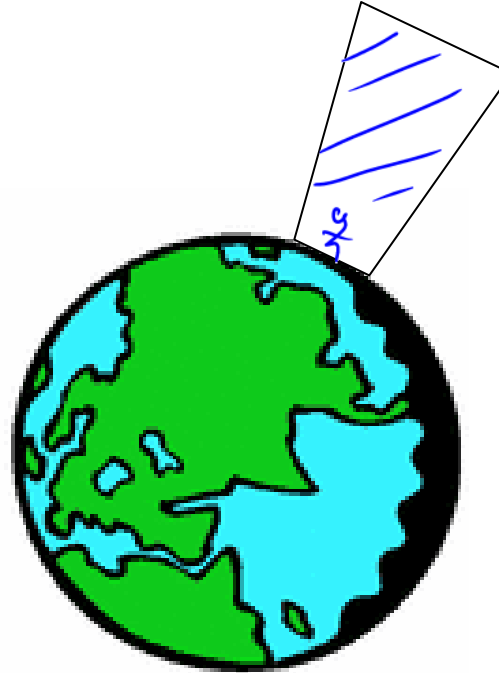
$$P = \frac{\textit{Force}}{\textit{Area}}$$

Demos: pressure vs. force; bed of nails (with sledgehammer!)

Why do they never show anyone *standing* on a bed of nails?

Atmospheric pressure: 1 atm = 14.70 lbs/in² (psi)
= 1.013×10^5 N/m² = pascal

Comes from.....



Demo: Collapsing can

Density

$$\rho = \frac{\text{mass}}{\text{volume}}$$

$$\frac{\text{kg}}{\text{m}^3}$$

$$\rho_{\text{water}} = 1000 \text{ kg/m}^3$$

$$\underline{\underline{\equiv 1.000 \text{ g/cm}^3}}$$

original definition of a gram

“Specific Gravity” = $\rho_{material} / \rho_{water}$
(i.e., the density in g/cm^3 units)

SG of some common substances:

Air, standard conditions	0.0013
Wood(Oak)	0.6 - 0.9
Liquid nitrogen	0.81
Ice	0.92
Water	1.00
Bricks	1.84
Aluminum	2.70
Steel	7.80
Silver	10.50
Lead	11.30
Gold	19.30
Platinum	21.40

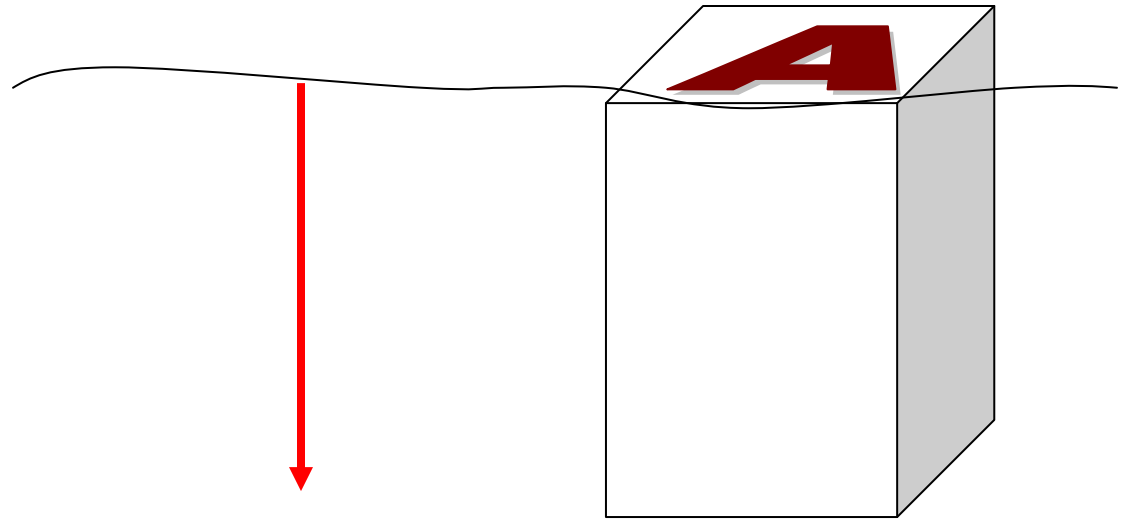
← 7800 kg/m^3

←

Pressure vs depth in a fluid

Weight of water above some area A at a depth of h .

$W =$



Pressure at h : (Include the pressure on the top of the fluid).

$P =$

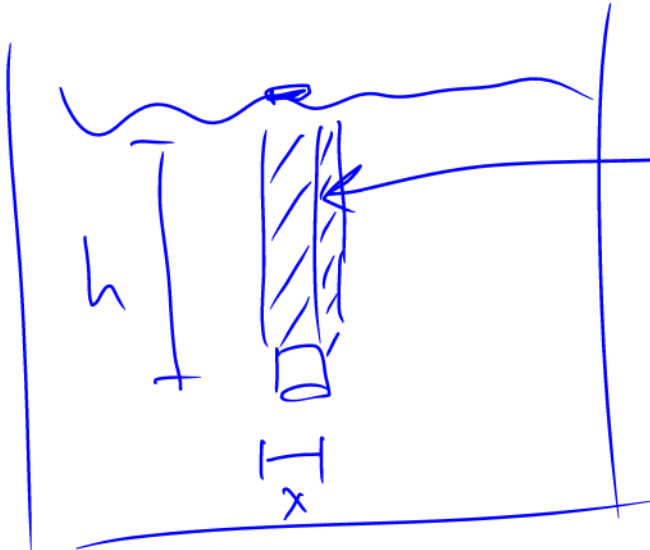
$\rho = \text{density}$

Videos

pressure vs depth, pressure pushes on all sides

$$P = P_0 + \rho g h$$

P at surface

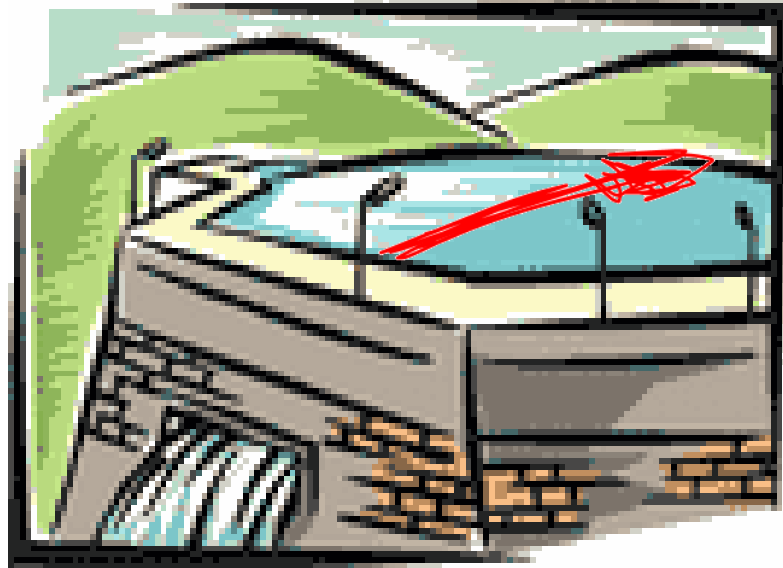


Additional pressure
= $\frac{\text{weight of water}}{\text{area}}$

$$\begin{aligned} W &= mg \\ &= (\rho V) g \\ &= (\rho) (h \cdot x \cdot x) g \\ &= \rho h x^2 g \end{aligned}$$

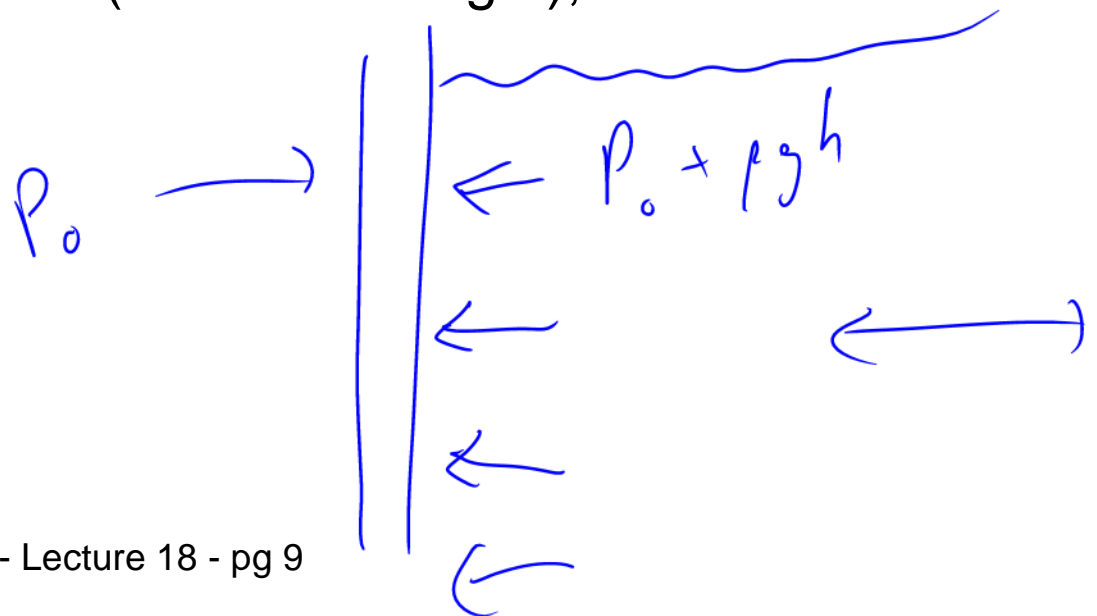
$$P = \frac{\rho h x^2 g}{x^2} = \rho g h$$

Clicker quiz



For a longer canyon behind the dam (red arrow length), the dam...

- a. can be weaker
- b. must be stronger
- c. can be the same.



From warmup

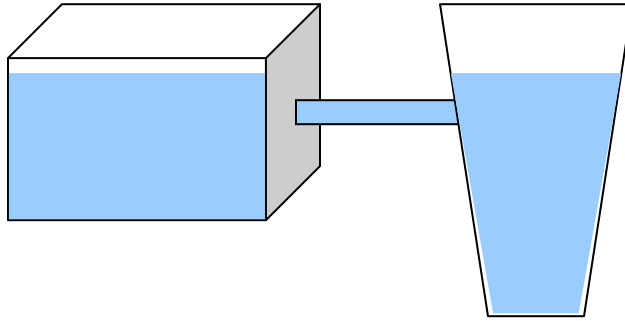
Where is the pressure greater, one meter beneath the surface of Lake Michigan or one meter beneath the surface of a swimming pool?

- a. Lake Michigan
- b. swimming pool
- c. the same

Pascal's principle

For a fluid at rest, the pressure in the fluid depends only on the depth, not the shape of the (open) container.

All parts of fluid at same depth have same pressure



Any change in pressure is felt by entire fluid

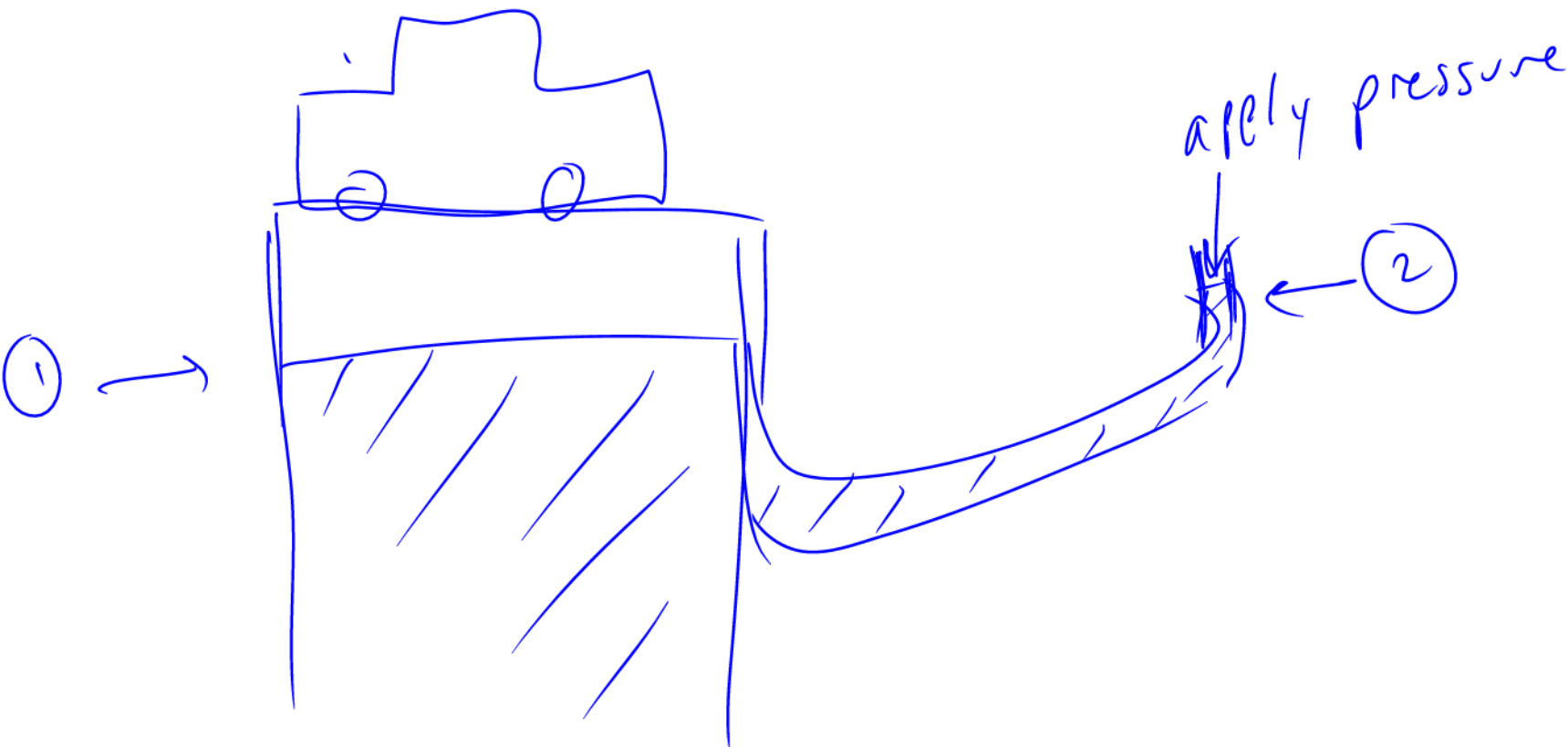
Demos

fluid levels

mechanical advantage

hydraulic "force amplification"

$$P_1 = P_2$$
$$F_1/A_1 = F_2/A_2$$
$$F_2 = F_1 \left(\frac{A_2}{A_1} \right)$$



From warmup

Ralph measures the pressure in his flat tire with a standard automotive pressure gauge. The gauge reads zero. This confuses Ralph, because he thinks there is probably still air in the tire. Help Ralph understand what is going on.

“**Pair share**”—I am now ready to share my neighbor’s answer if called on.

a. Yes

“Absolute” vs “gauge” pressure

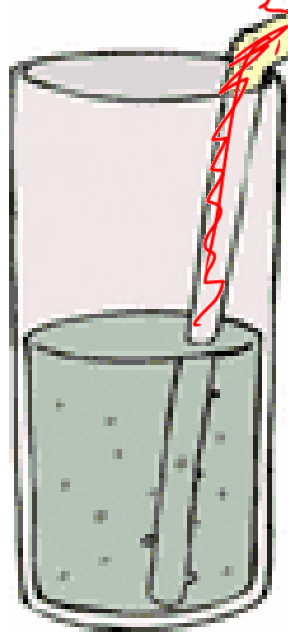
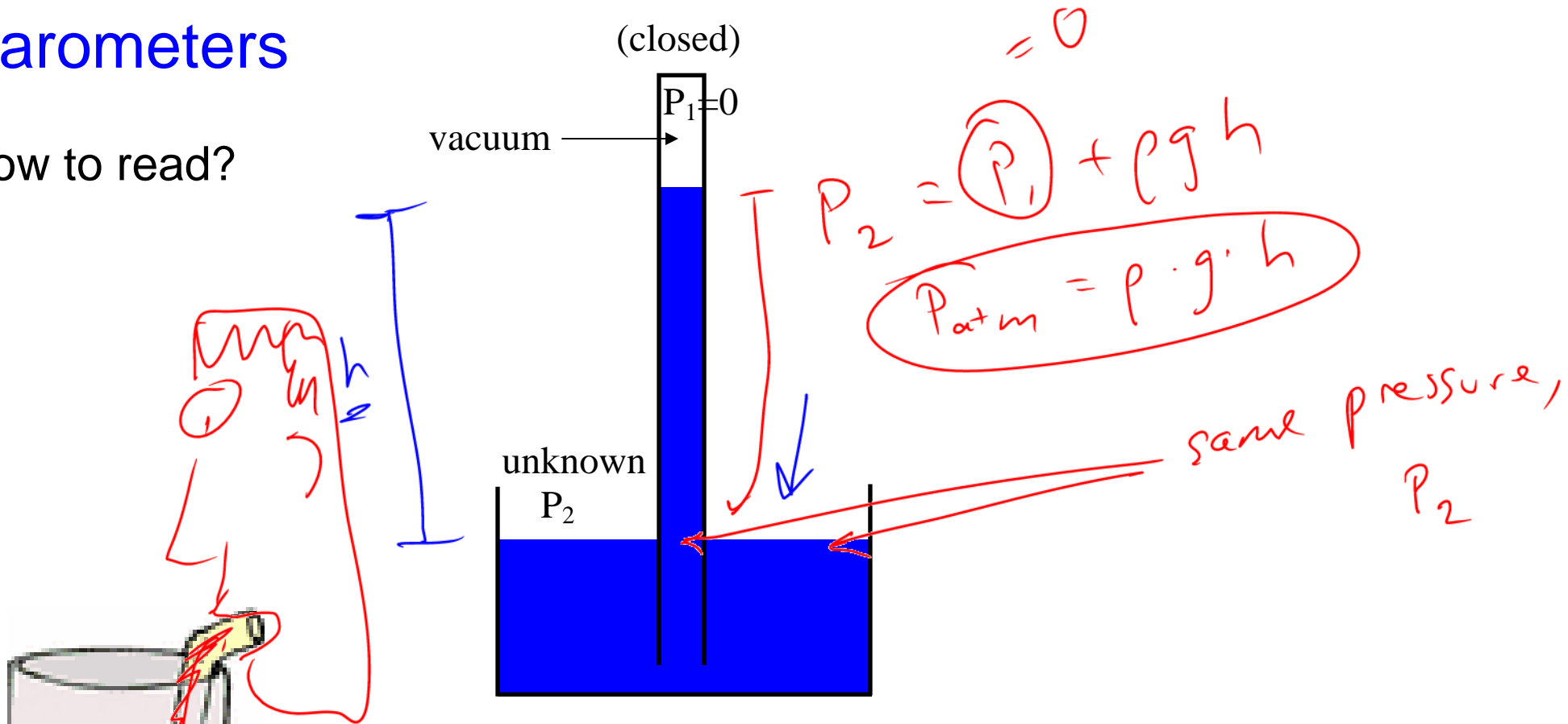
Gauge pressure is: the pressure a gauge reads

$$P_{\text{gauge}} = P_{\text{abs}} - P_{\text{atmospheric}}$$

↑

Barometers

How to read?

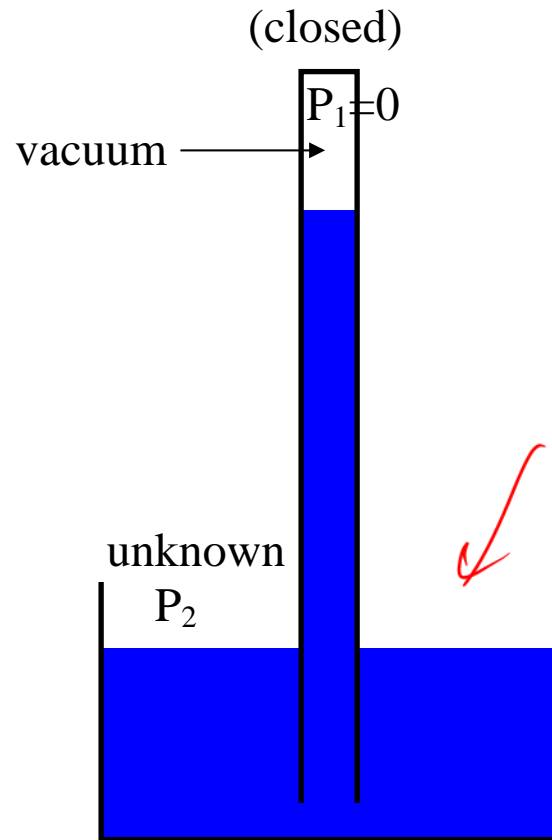


Straws:

How high can we lift water with a vacuum?

$$h = \frac{P_{atm}}{\rho g} = \frac{101000 \text{ Pa}}{\left(9.8 \frac{\text{m}}{\text{s}^2}\right) \left(1000 \frac{\text{kg}}{\text{m}^3}\right)} \approx \boxed{10 \text{ m}}$$

Clicker quiz



On the moon, where gravity is less but there is no atmosphere, if you pump out the air at the top of a barometer, the mercury would rise _____ compared to on earth.

- a. higher
- b. lower
- c. the same
- d. not at all

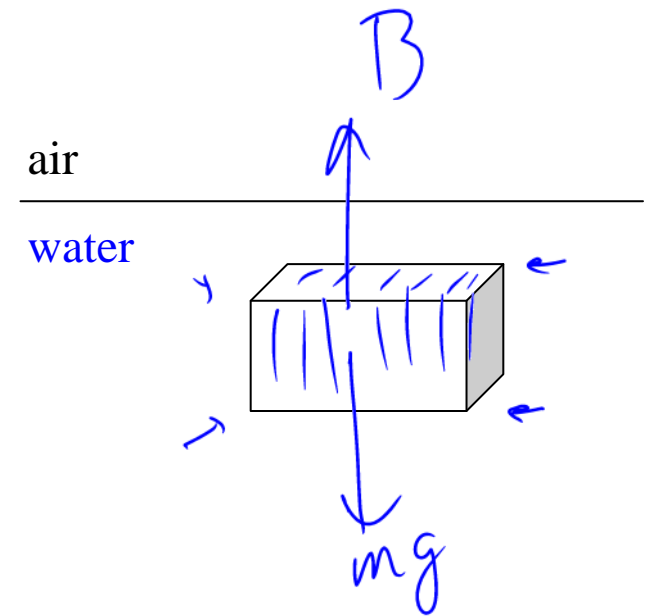
Buoyancy

Water in a rectangular plastic bag...

Does the water inside the bag have mass?

Does the water inside the bag have weight?

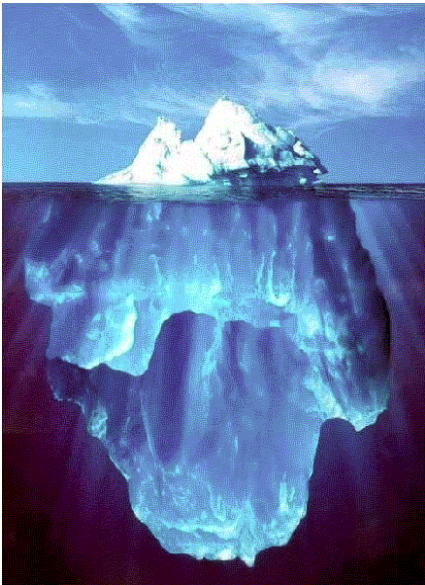
Why doesn't it accelerate down?



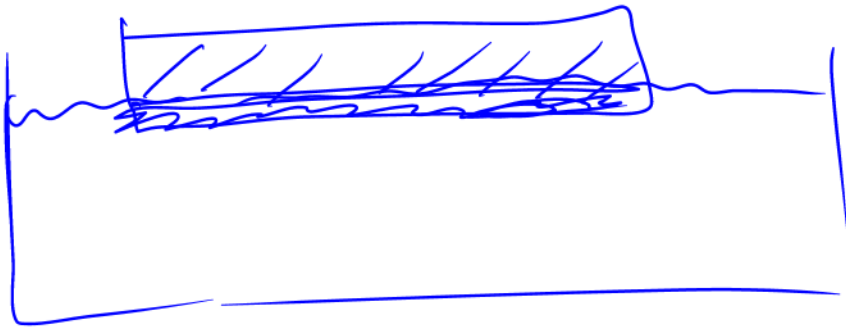
$$B = m_{\text{water}} g$$

Archimedes' Principle

The buoyant force equals the weight of the fluid that the object is displacing at the moment.



$$F_{\text{Buoyant}} = B = m_{\text{displaced fluid}} \times g$$
$$= \rho_{\text{fluid}} V_{\text{object}} g$$



Demos

- Does a ~~bottle~~ ^{can} of ~~Coke~~ ^{Crush} sink or float?
- Does aluminum foil sink or float?

a. sink
b. float

From warmup

The buoyant force of a submerged object always equals:

a. the weight of the object

b. the net force on the object

c. the weight of the water that would otherwise occupy the object's space

Sink vs. Float

Objects will **sink** if $\text{density} > \text{density of water}$

Objects will **float** if $\text{density} < \text{density of water}$

Floating objects will rise out of the water until...

$$B = \rho_{fl} V_{obj} g$$

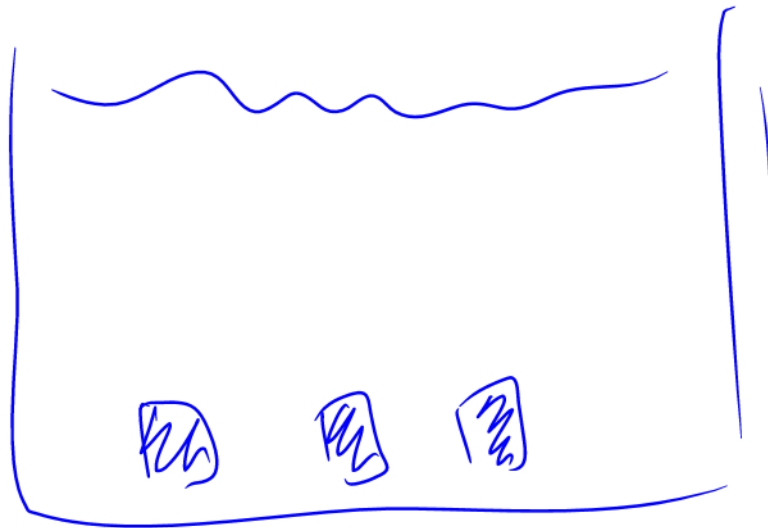
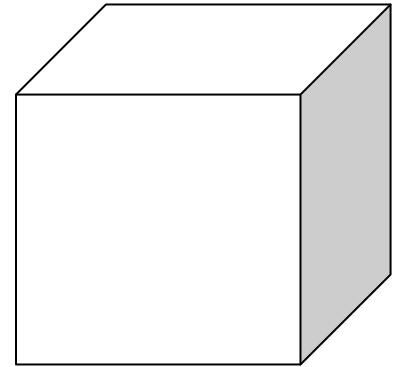
↑
submerged

submerged volume is
small enough so $B = mg$

Clicker quiz

Three cubes of the same size and shape are put in water. They sink. One is lead, one is steel and one is a dense wood (ironwood). $\rho_{\text{lead}} > \rho_{\text{steel}} > \rho_{\text{ironwood}}$. The buoyant force is greatest on the _____ cube

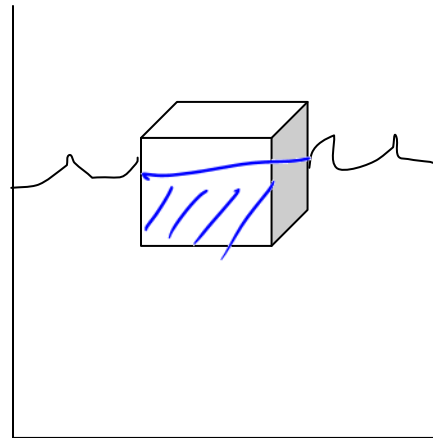
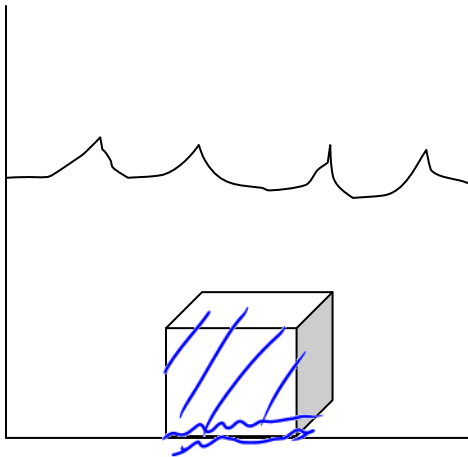
- a. lead
- b. steel
- c. wood
- d. same buoyant force



Clicker quiz

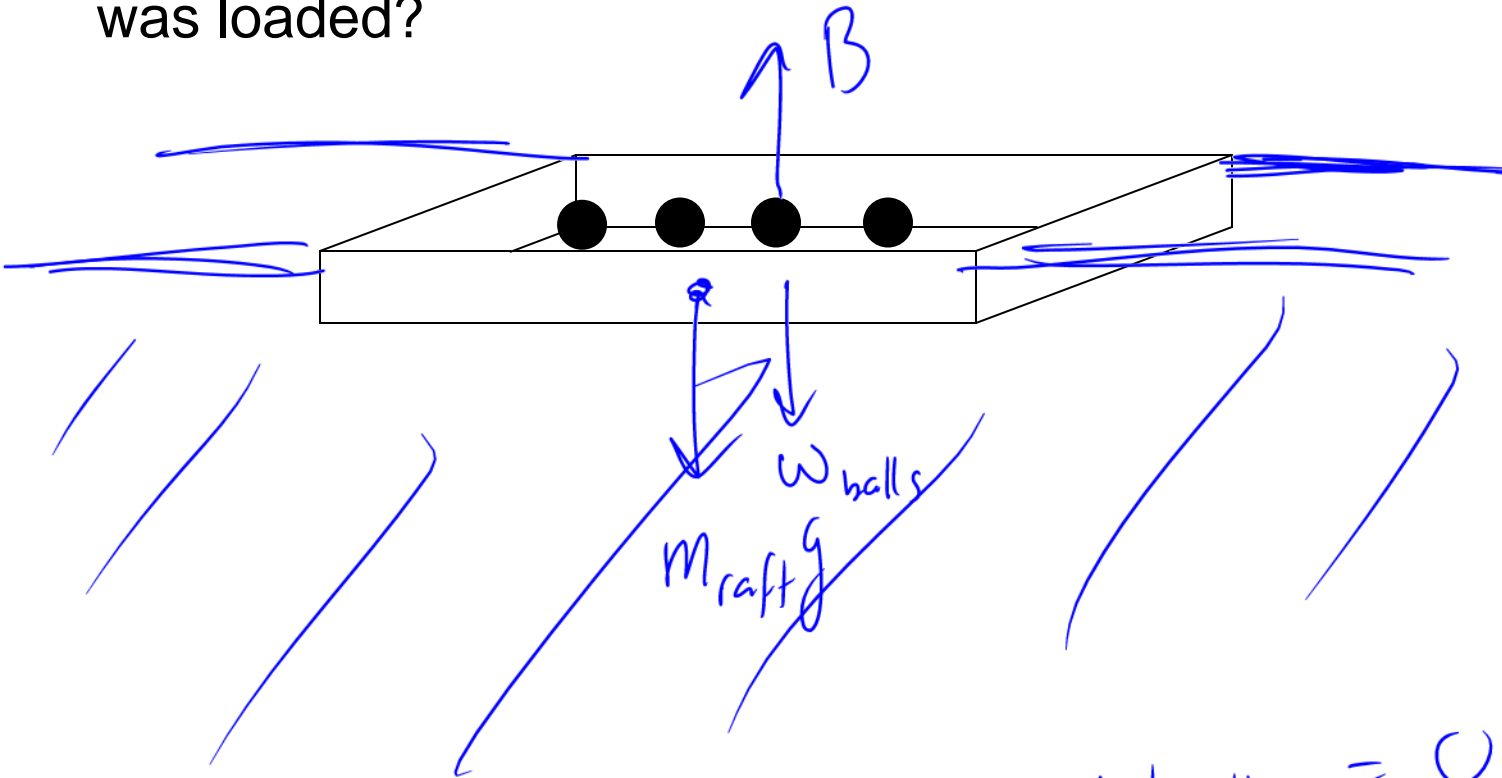
Two cubes of the same size and shape are made out of wood. The ironwood cube **sinks**, but the walnut cube **floats**. The buoyant force is greatest on the _____ cube

- a. ironwood
- b. walnut
- c. same buoyant force



Worked Problem

A raft of wood of size $0.5\text{m} \times 6\text{m} \times 5\text{m}$ weighs $30,000\text{ N}$. It is loaded with cannon balls until it is (barely) completely submerged. How much weight was loaded?



$$\sum \vec{F} = 0 \rightarrow B - m_{\text{raft}}g - w_{\text{balls}} = 0$$

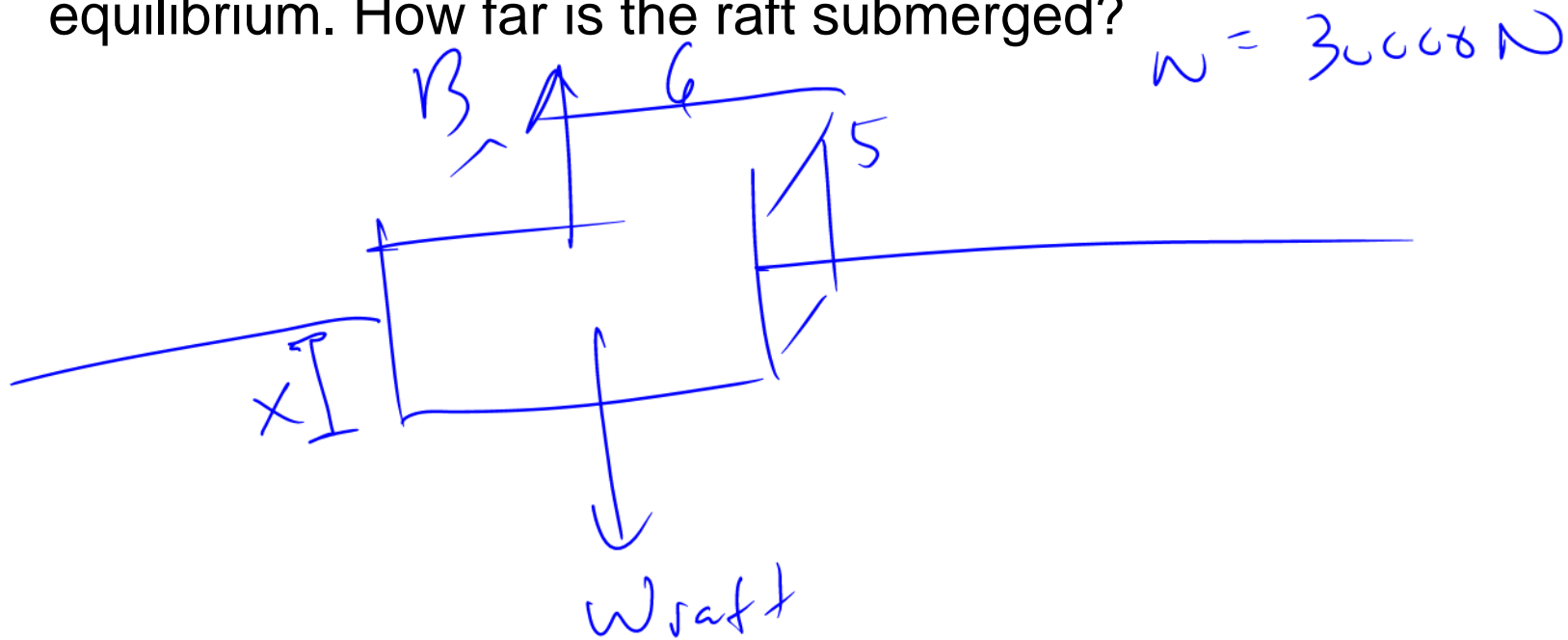
$$\rho_{\text{fl}} V_{\text{obj}} g - (30000\text{ N}) = w_{\text{balls}}$$

$$(1000) (.5 \cdot 6 \cdot 5) (9.8) - 30000 = w_{\text{balls}}$$

Answer: $117,000\text{ N}$

$$w_{\text{balls}} = 117000\text{ N}$$

Additional part: the balls are unloaded, and the raft now sits at equilibrium. How far is the raft submerged?



$$\sum F = 0 \rightarrow B = W_{\text{raft}}$$

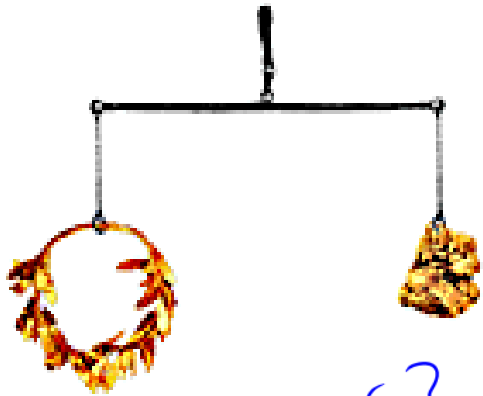
$$\rho_{\text{fl}} V_{\text{obj}} g = 30000 \text{ N}$$

$$(1000)(6 - 5 \cdot x)(9.8) = (30000)$$

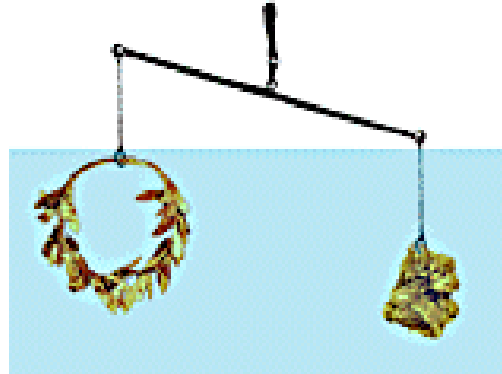
Solve for x

Answer: 10.2 cm

Archimedes: "Eureka"



Same?



Same B?

Archimedes was charged with determining if a crown was pure gold. One method he may have used: he balanced the crown with pure gold outside water. After immersing, the balance tipped as shown.

Clicker quiz: The crown has density

- a. more than gold
- b. less than gold
- c. same as than gold

Clicker quiz 1: A cannonball is put in a boat. The boat sinks down to displace more water. The amount of new water displaced is

- a. a volume of water that weighs **more than** the cannonball
- b. a volume of water that weighs **as much as** the cannonball
- c. a volume of water that weighs **less than** the cannonball

Clicker quiz 2: If the cannonball now falls from the boat into the water and sits on the bottom of the lake, the amount of water displaced by the cannon is

- a. a volume of water that weighs **more than** the cannonball
- b. a volume of water that weighs **as much as** the cannonball
- c. a volume of water that weighs **less than** the cannonball

From warmup (do as clicker quiz): Therefore...if the cannonball falls from the boat into the water and sits on the bottom of the lake, will the overall water level of the lake rise, fall or stay the same? (compared to when the cannonball was in the boat)

- a. rise
- b. fall
- c. stay the same

Problem-Solving Tip: Limiting Cases

What happens if the cannonball has a very large density?

What happens if the cannonball has a very small density?