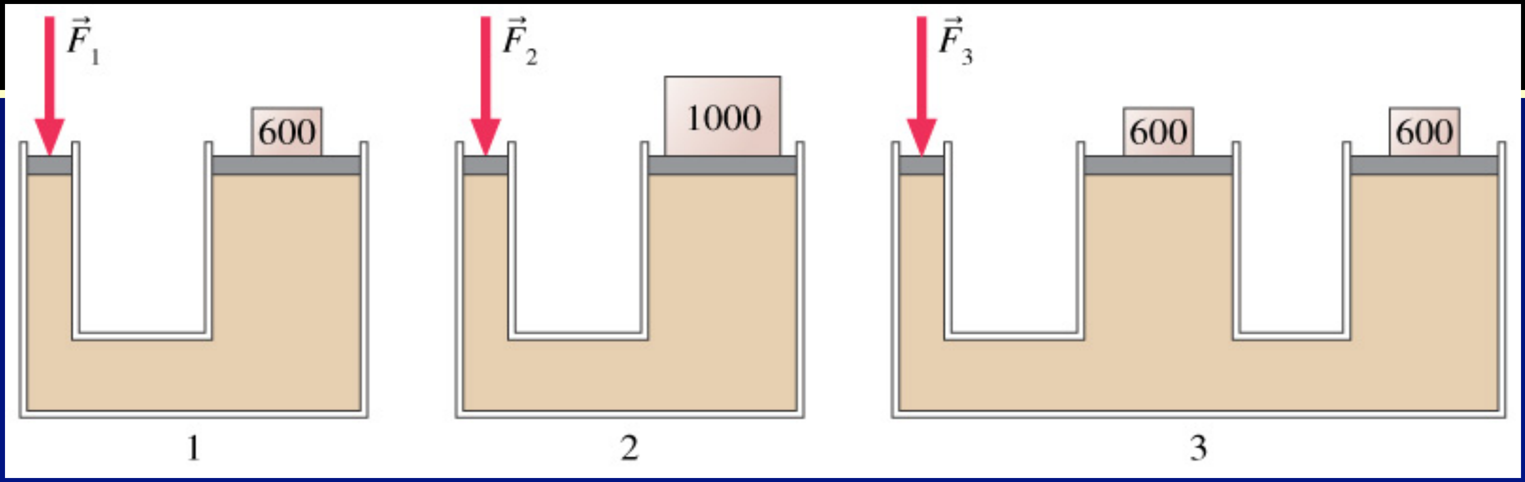
Physics 1021

Spring 2012, 15a

ConcepTest 15.1 Hydraulic Lift

- Rank in order, from largest to smallest, the magnitudes of the 3 forces required to balance the masses in the Figure. The masses are in kilograms.

A. $F_1 = F_2 = F_3$
B. $F_3 > F_2 > F_1$
C. $F_3 > F_1 > F_2$
D. $F_2 > F_1 > F_3$
E. $F_2 > F_1 = F_3$



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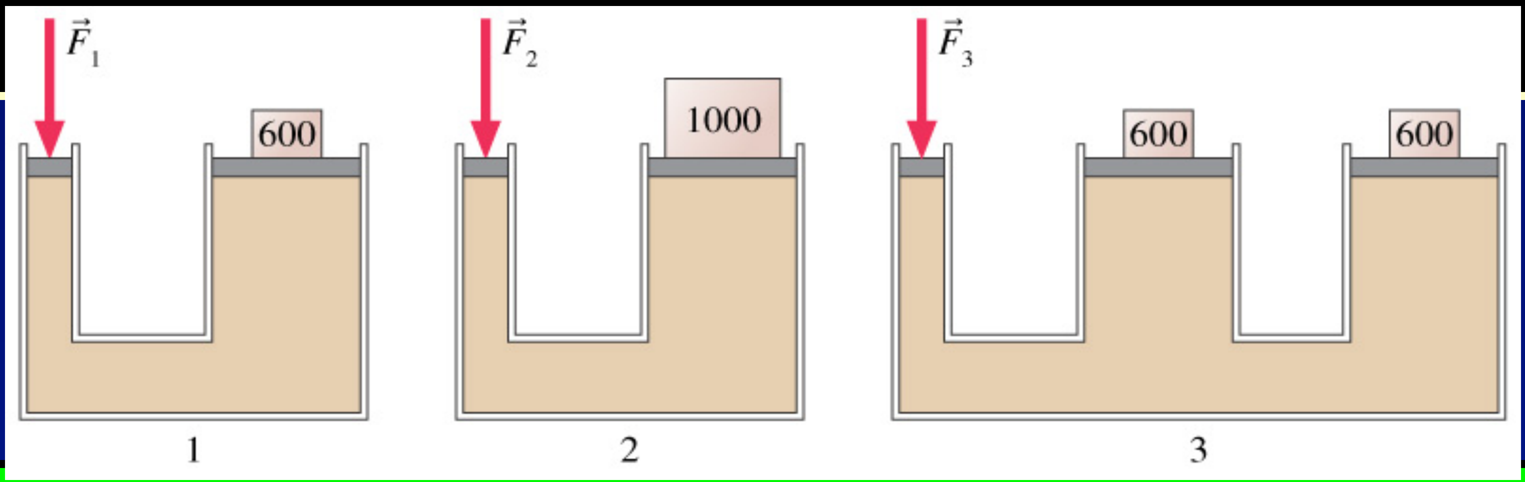
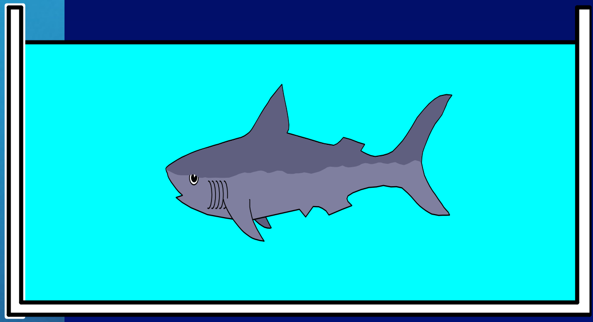


Draw the FBD for each weight. The pressure in the fluid for 1 and 3 is the same, and equals 600*9.8/A. Thus the force applied is the same for 1 and 3.

Chapter 15
Fluids



- **Fluids at rest**
  - **density, pressure**
  - **pressure in fluids -- *pressure vs. depth***
  - **Archimedes' principle -- *buoyancy***
- **Fluids in motion**

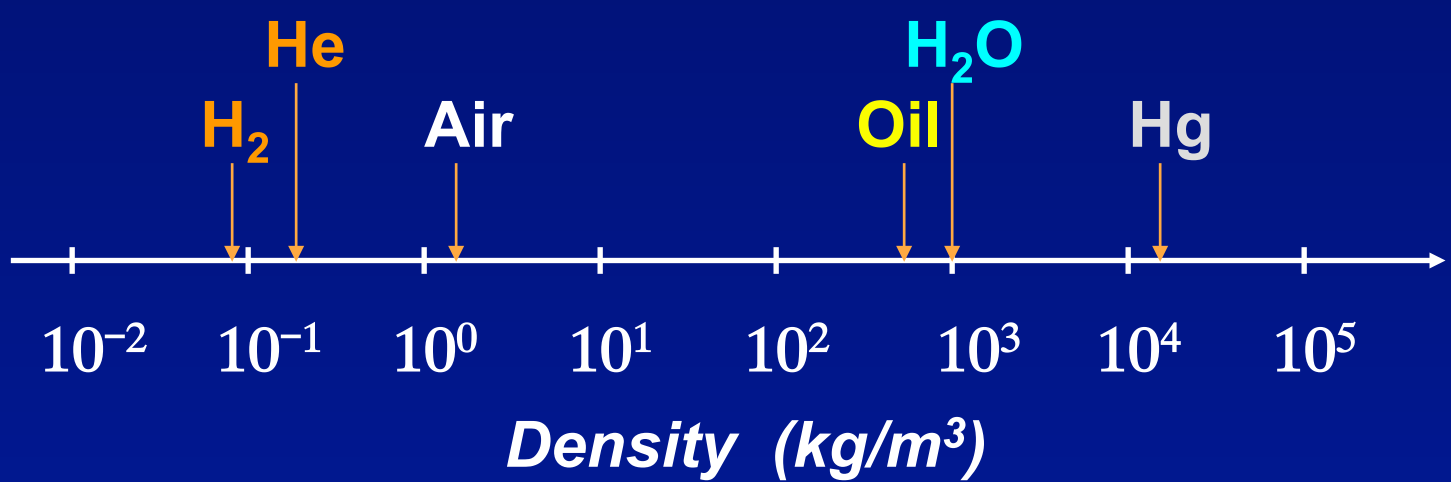
Density

- Density = Mass / Volume
  - units are kg/m^3

$$\rho = \frac{m}{V}$$

Some common densities:

air at sea level	1.29 kg/m^3
water	1000 kg/m^3



Pressure

- Pressure = Force / Area
  - units are N/m^2 ≡ Pascals

$$p = \frac{F}{A}$$

same force, *different* pressure

Atmospheric Pressure P_0

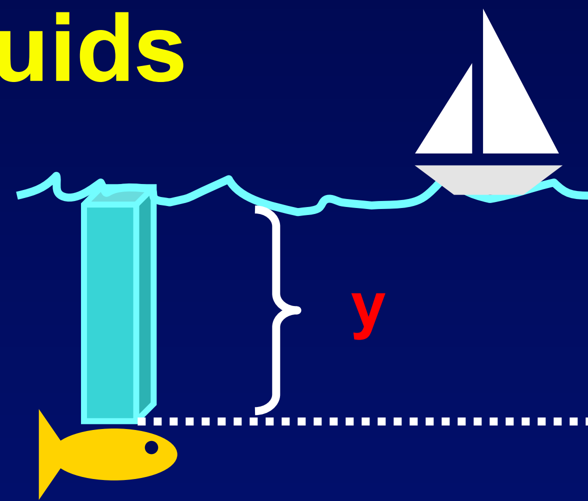
P_0 = 1.013×10^5 Pa (or 1 atm)

Simple organisms survival

- The maximum pressure any organism can survive is about 913 times atmospheric pressure.
- Only small, simple organisms such as tadpoles and bacteria can survive such high pressures.

Fang-toothed fish
5000 m

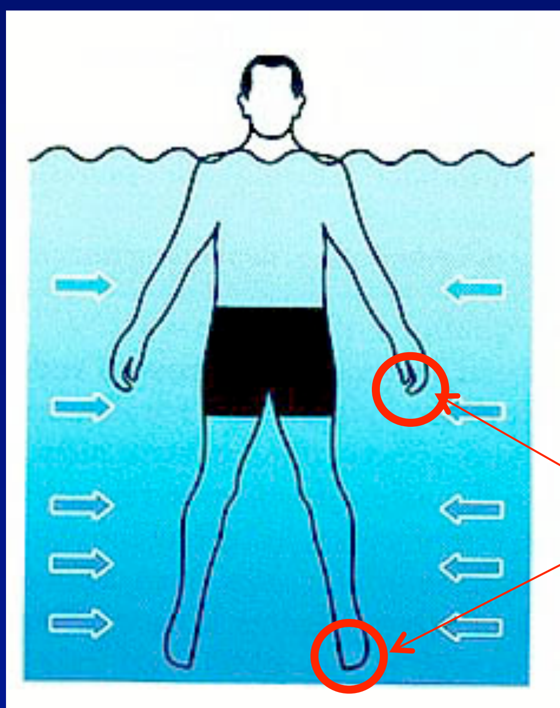
Pressure in Fluids



Pressure at depth y is due to the *weight* of the fluid above that point

Inside the liquid: $P_{total} = P_{surface} + P_{water}$

$$P_{total} = P_0 + \rho g y$$



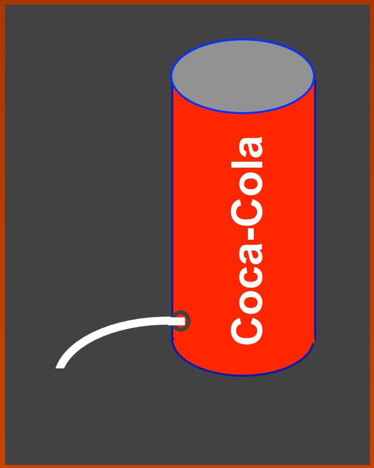
Pressure <u>increases</u> with depth !!

Pressure is constant at a given depth - hydrostatic

ConcepTest 15.2 The falling bucket

When a hole is made in the side of a Coke can holding water, water flows out and follows a parabolic trajectory. If the container is dropped in free fall, the water flow will:

1) continue downward but at a reduced rate
2) stop altogether
3) go out in a straight line
4) curve upwards



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(3) go out in a straight line

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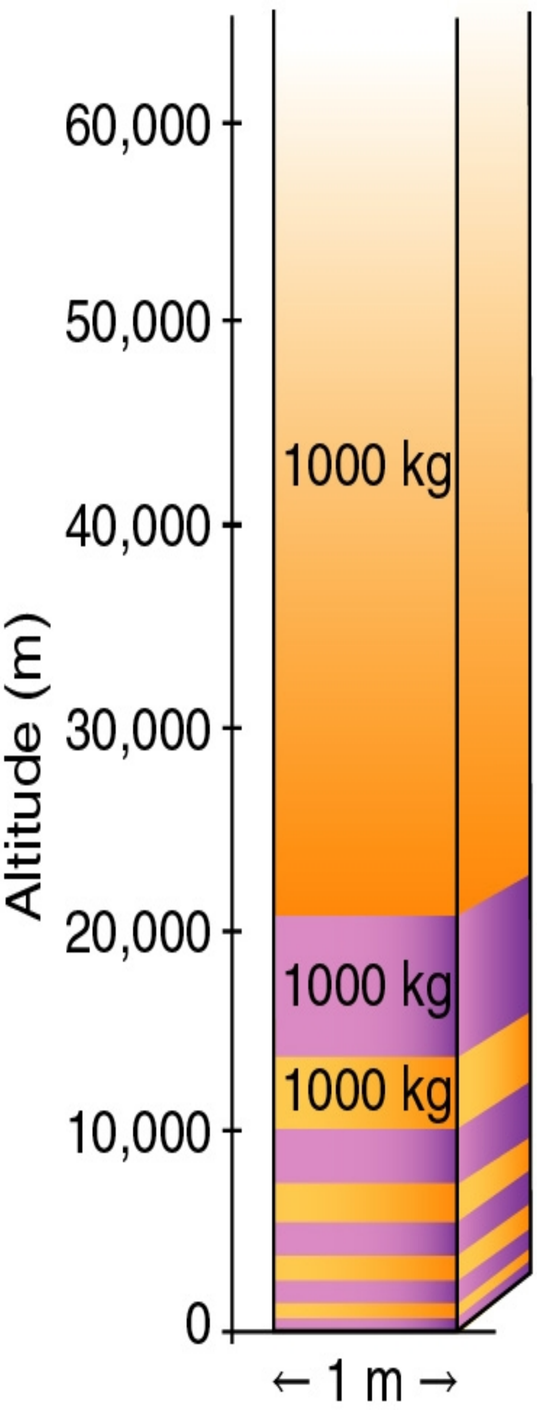
Water flows out of the hole because the **water pressure inside** is larger than the **air pressure outside**. The water pressure is due to the ***weight*** of the water. When the can is in free fall, the water is ***weightless***, so the water pressure is zero, and hence no water is pushed out of the hole!

The Atmosphere

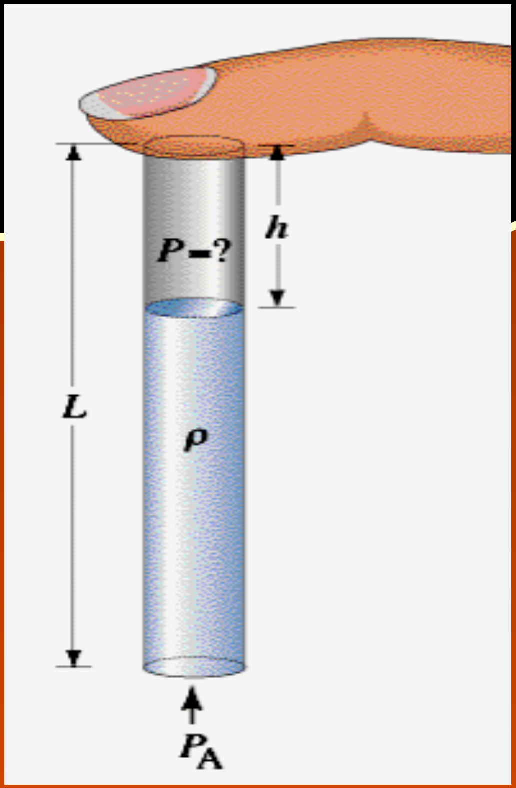
- Air can be heavy!
- Air at ground level supports air overhead
  - air pressure is highest near the ground
  - air density is highest near the ground
- Key observations:
  - air pressure decreases as you go up
    - ✓ water pressure increases with depth
  - more force at bottom than at top
  - force imbalance yields a **net upward force** called the ***buoyant force***



ConcepTest 15.3(Pre)The straw

- You put a straw into a glass of water, place your finger over the top so no air can get in or out, and then lift the straw from the liquid. You find that the straw retains some liquid. How does the air pressure P in the upper part compare to atmospheric pressure P_A?

1) greater than P_A
2) equal to P_A
3) less than P_A



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(1) greater than P_A

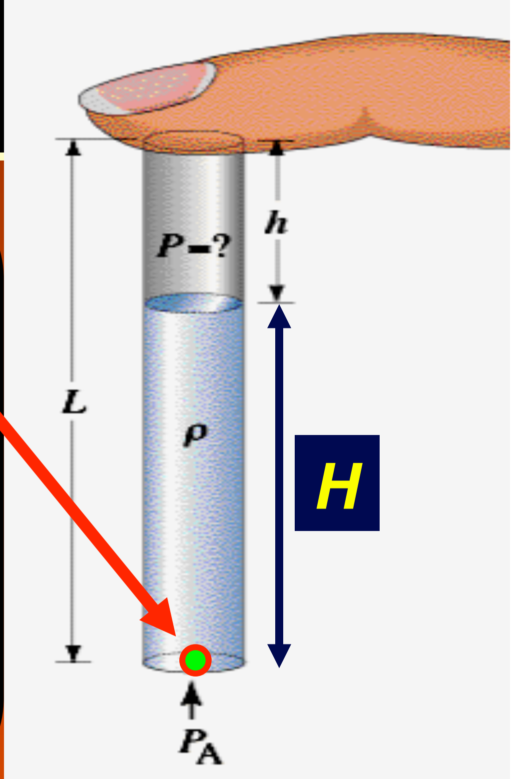
(2) equal to P_A

(3) less than P_A

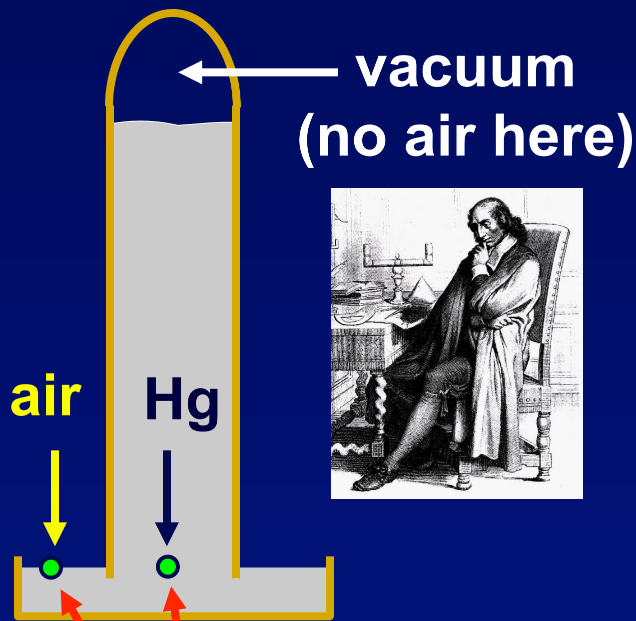
Consider the forces acting at the bottom of the straw: $P_A - P - \rho g H = 0$

This point is in equilibrium, so net force is zero.

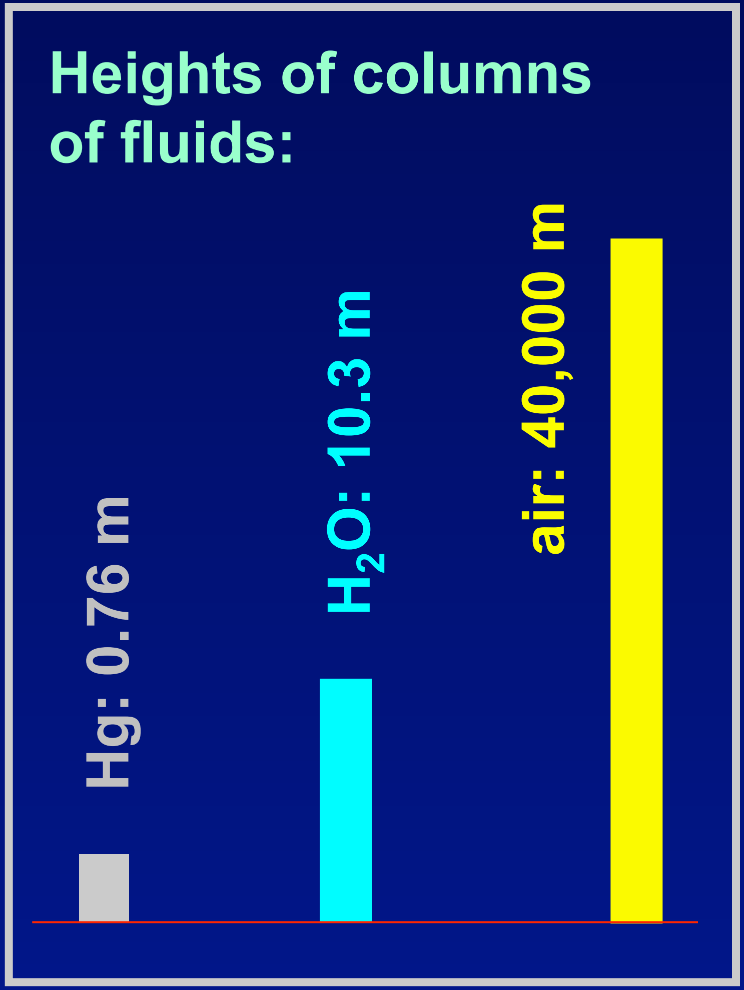
Thus: $P = P_A - \rho g H$ and so we see that the pressure P inside the straw must be <u>*less*</u> than the outside pressure P_A.



The Barometer



pressure at these two points
due to air and Hg must be equal



Simple organisms survival

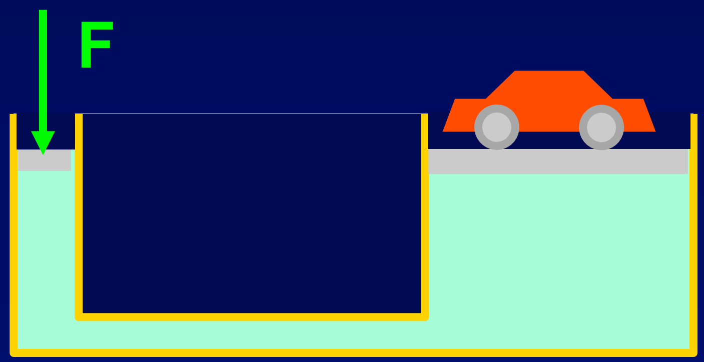
- The maximum pressure most organisms can survive is about 913 times atmospheric pressure.
- Only small, simple organisms such as tadpoles and bacteria can survive such high pressures.
- Assume that the density of seawater is 1025 kg/m^3
- What then is the maximum depth at which these organisms can live under the sea?

Fang-toothed fish
5000 m

Open and Closed Containers

- For a fluid in a closed container:
  (assume incompressible fluid)

  Pressure depends on depth as well as external forces

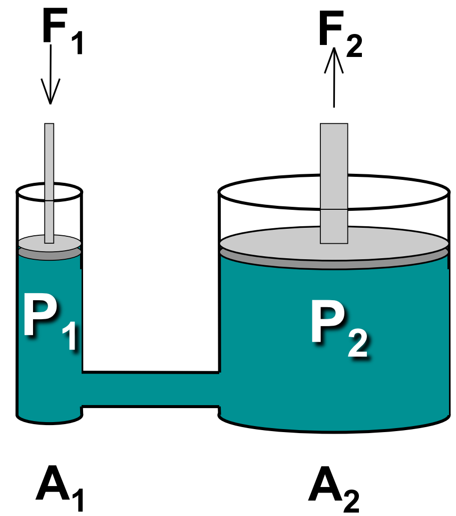


- Pascal's Principle: change pressure (by an external force) in one place, then pressure will change everywhere

  - pressure transmitted through fluid

$$P_1 = P_2$$

$$F_1 / A_1 = F_2 / A_2$$

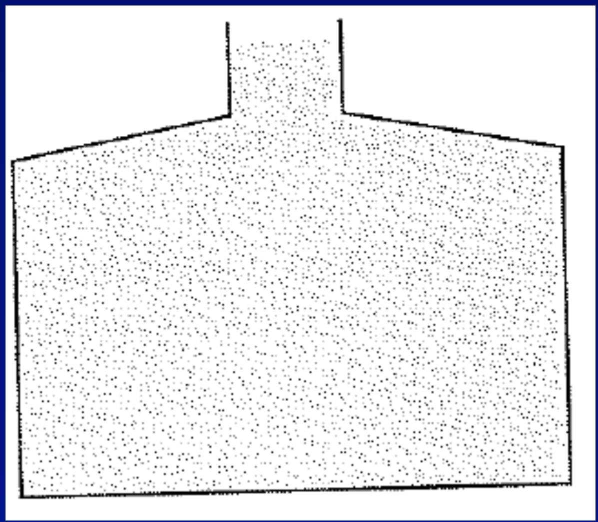


Ponderable: Shake the dressing

The container shown holds a mixture of oil and water. To begin, the container is shaken vigorously to mix the oil into the water by breaking it into very tiny droplets. This is what happens when you shake a jar of salad dressing. Eventually, the oil separates and rises to the top. Oil and water are *immiscible, meaning that the total* volume is the same whether they are mixed or separated.

The pressure at the bottom of the container after the oil has separated is *not the same as the initial pressure when the oil and water are mixed,* although it may take some careful thought to understand why.

Is the final pressure at the bottom higher or lower than the initial pressure? Explain.

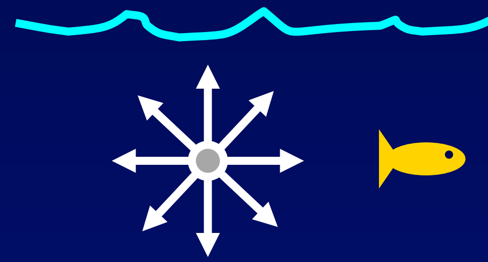


Buoyancy

New Topic

Buoyancy

Fluid is in static equilibrium:
pressure the same in all directions!

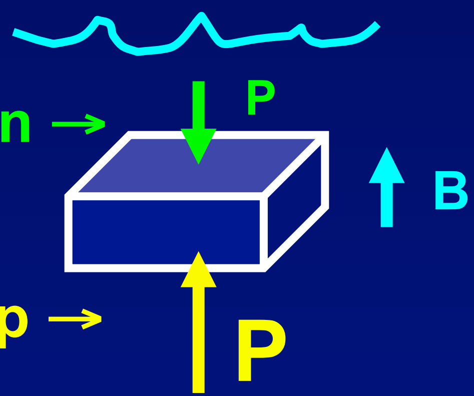


Recall that pressure depends on depth:

this pressure down →

is less than

this pressure up →



Net force UP

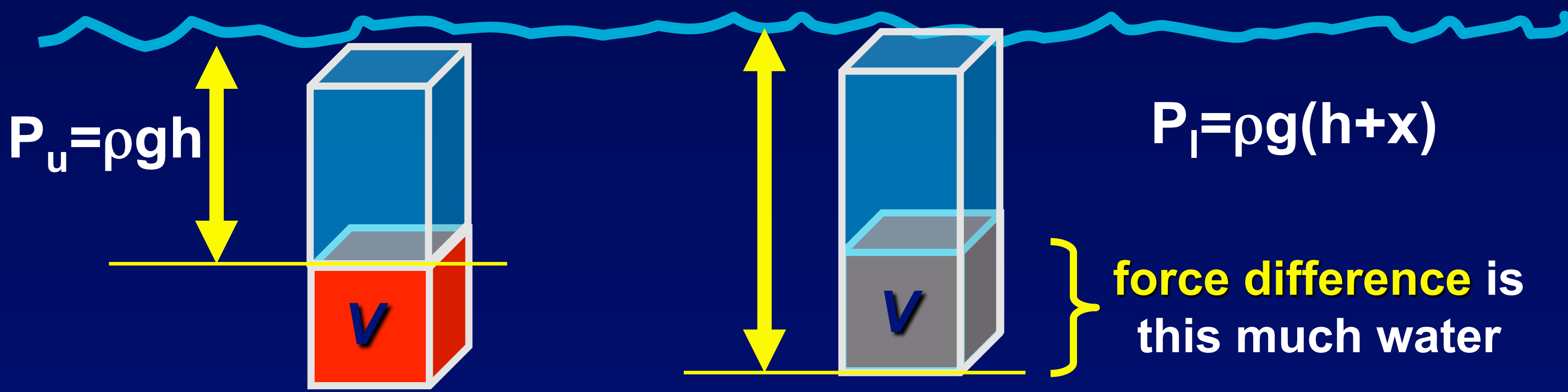
Buoyant force

Buoyant force UP $\propto$ volume of the object

Bigger area for object ⇒ larger force

Bigger height of object ⇒ larger pressure difference

Buoyancy



force on **top** due to this much water

force on **bottom** due to this much water

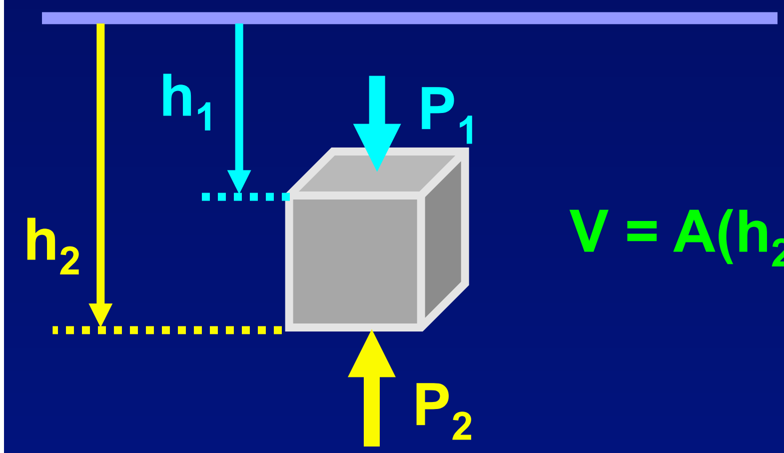
Buoyant force due to *different forces* at top and bottom of object !!

$$F = (P_u - P_l)A = \rho g V$$

F is the weight of the displaced water, Archimedes Principle

Archimedes' Principle

Buoyant force comes from the *different pressures* at the top and the bottom of the object !



$V = A(h_2 - h_1)$

$$\begin{aligned} F_B &= F_2 - F_1 \\ &= P_2 A - P_1 A \\ &= \rho_{fluid} g h_2 A - \rho_{fluid} g h_1 A \\ &= \rho_{fluid} A(h_2 - h_1) g \\ &= \rho_{fluid} V g \end{aligned}$$

Archimedes' Principle:

Buoyant force $F_B = \rho_{fluid} V g$ **(weight of fluid displaced)**

ConcepTest 15.4 Archimedes V

Two beakers are filled to the brim with water. A wooden block is placed in the second beaker so it floats. (Some of the water will overflow the beaker). Both beakers are then weighed. Which scale reads a **larger weight?**

1

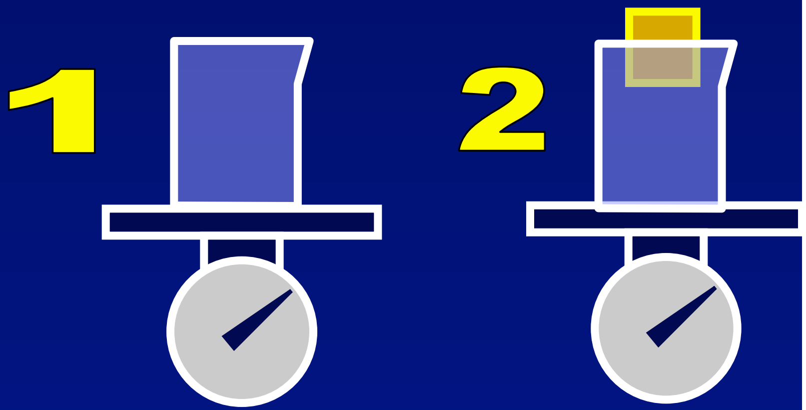
2

3 same for both

ConcepTest 15.4 Archimedes V

- Two beakers are filled to the brim with water. A wooden block is placed in the second beaker so it floats. (Some of the water will overflow the beaker). Both beakers are then weighed. Which scale reads a larger weight?

The block in B displaces an amount of water equal to its weight, since it is floating. That means that the weight of the overflowed water is equal to the weight of the block, and so the beaker in B has the same weight as that in A.

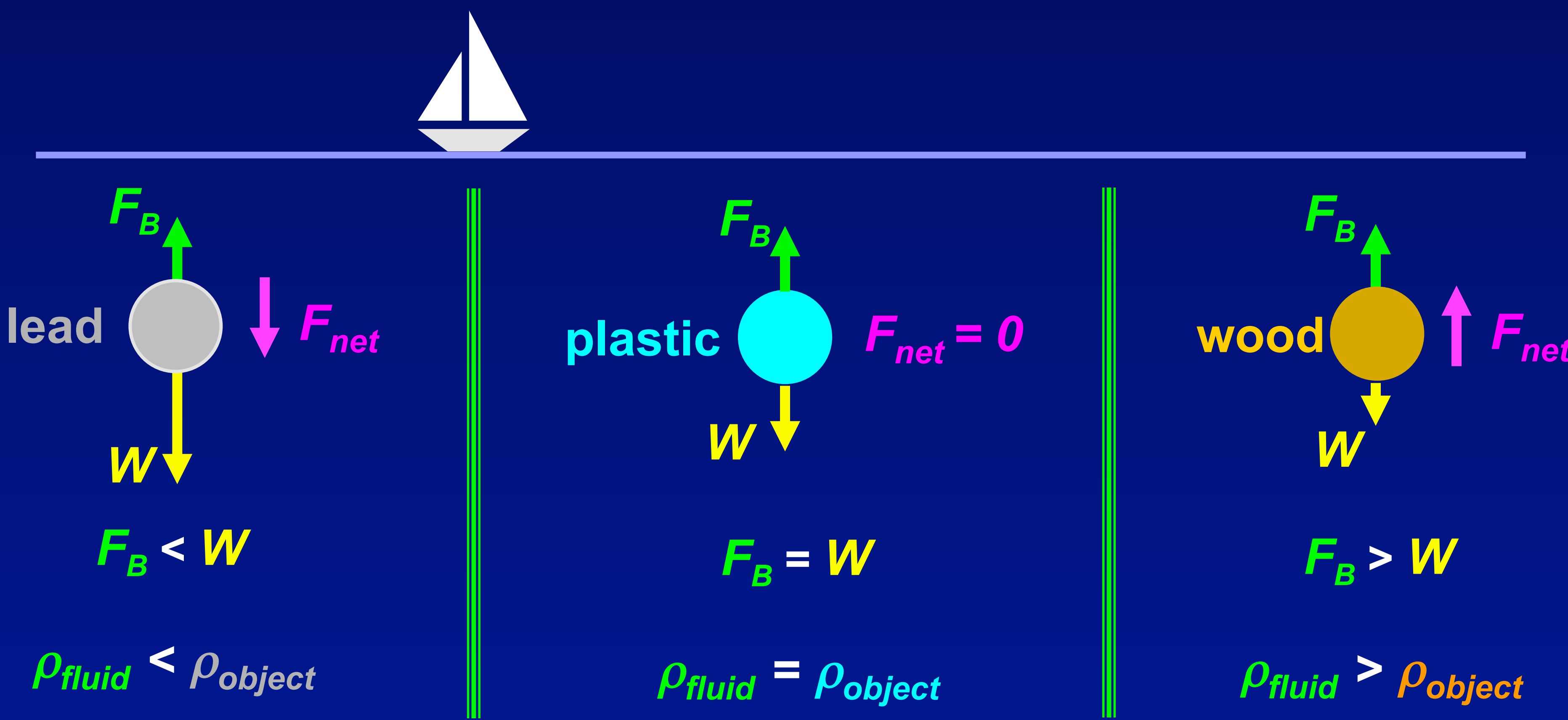


3 same for both

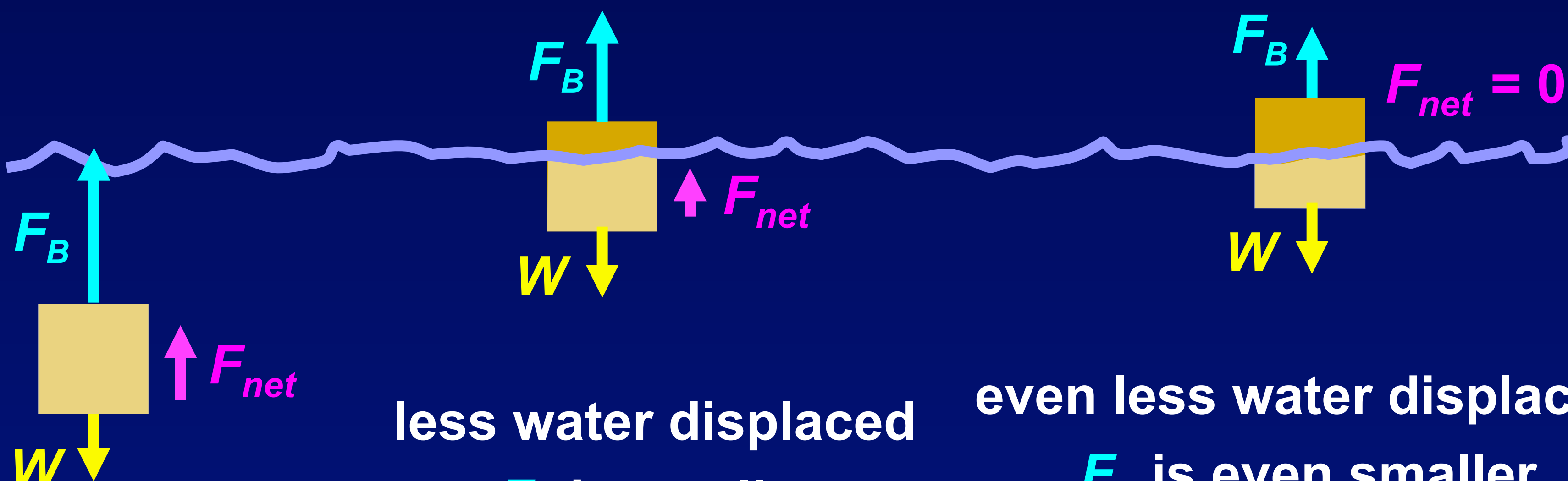
Does it float or sink?

Consider UP and DOWN forces (*i.e.* the *net force*) on object:

$$F_{net} = F_B - W = (\rho_{fluid} - \rho_{object})\, V g$$



Floating Objects



less water displaced

F_B is smaller

but still $F_B > W$

even less water displaced

F_B is even smaller

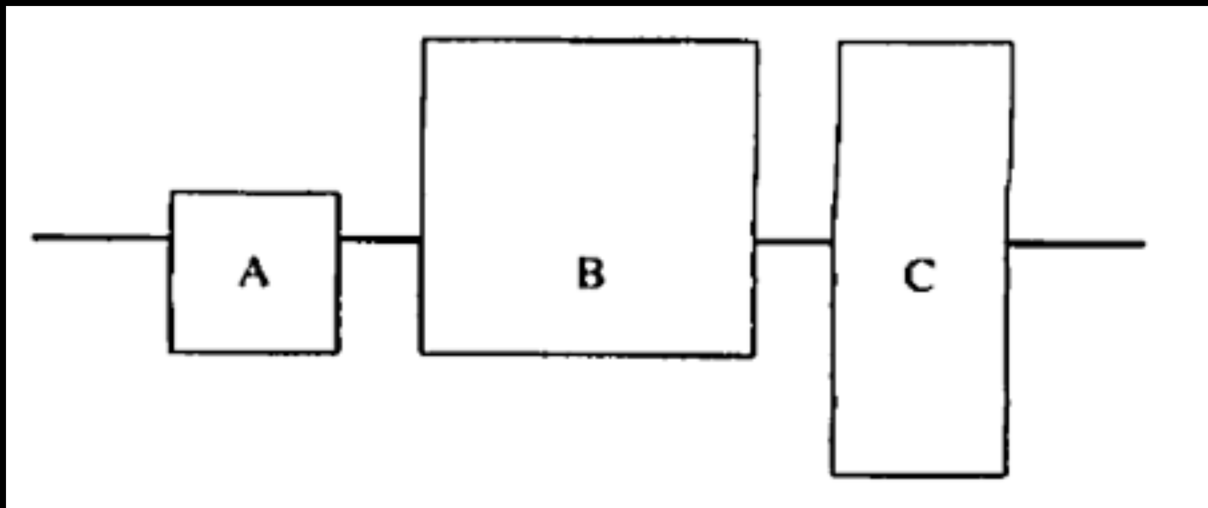
$F_B = W$

To float on the surface, the *net force* must be zero:

F_B (force up) = W (force down)

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

ConcepTest 15.5 Rank the densities



From high to low:

(1) a,b,c

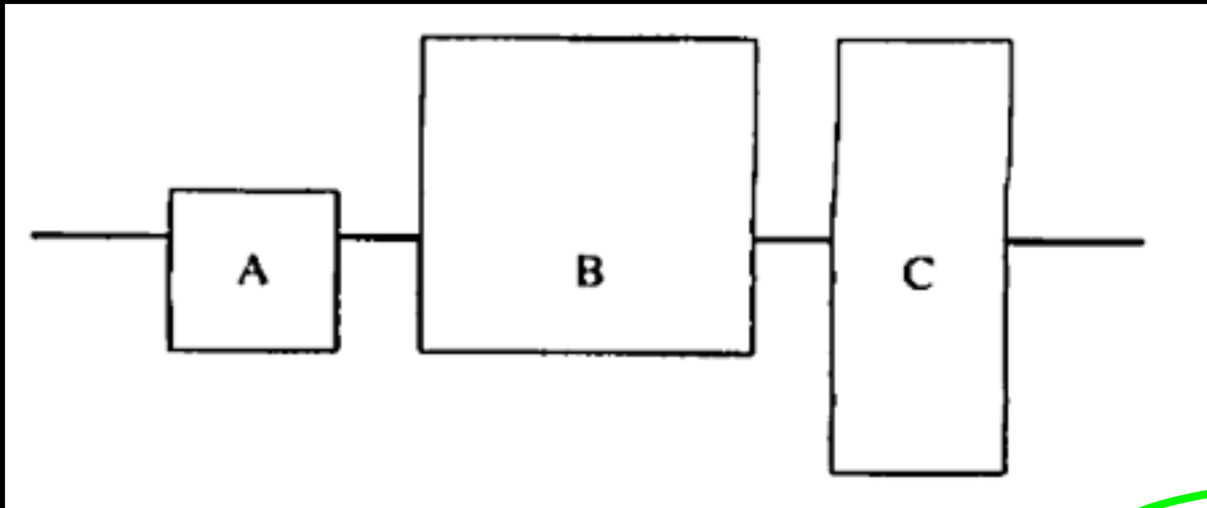
(2) c,b,a

(3) All are equal

(4) b,c,a

(5) a,c,b

ConcepTest 15.5 Rank the densities



From high to low:

(1) a,b,c

(2) c,b,a

(3) All are equal

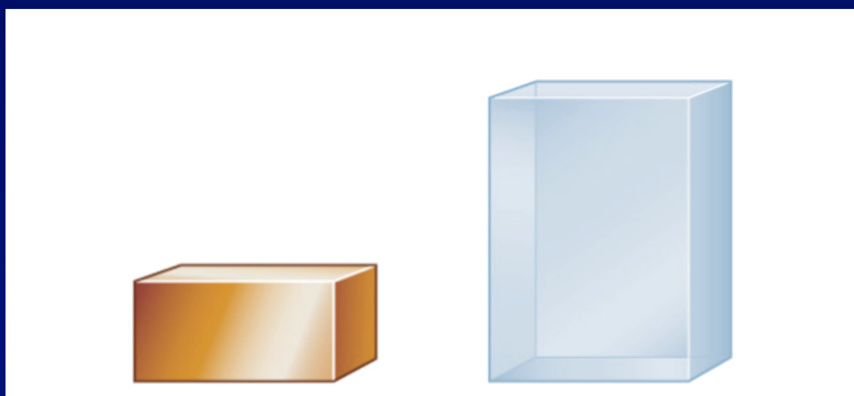
(4) b,c,a

(5) a,c,b

All three are less dense than the liquid, since they are floating above the surface. The relative volume displaced by B is the least and by A is the most, so these are the least and most dense respectively

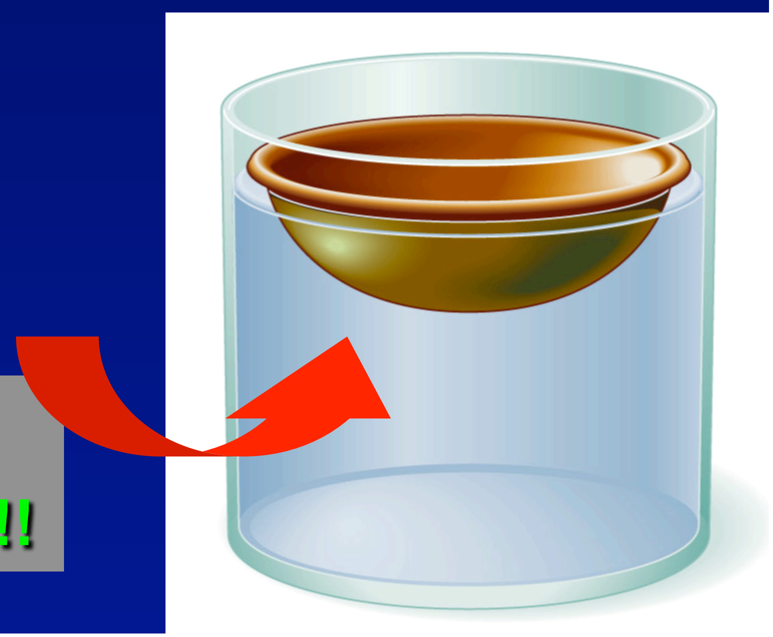
equal weights of
wood and water

wood has a larger volume ⇒⇒ wood floats



equal weights of
copper and water

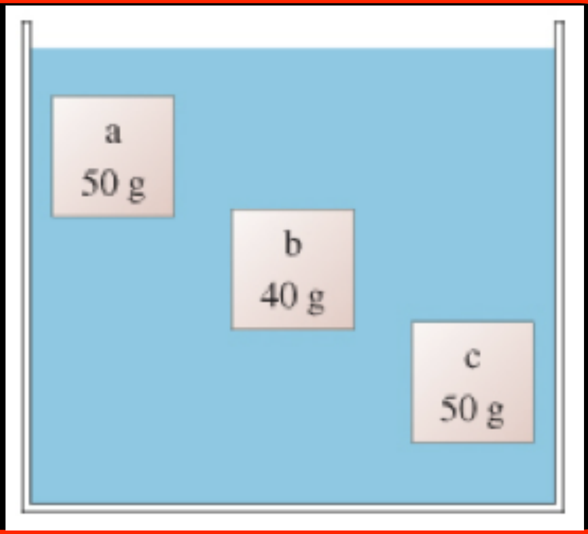
copper has a smaller volume
⇒⇒ copper sinks



How do we get copper to float?
Increase volume of displaced water!!

ConcepTest 15.6

Rank the buoyant forces
All 3 have same volume



From high to low:

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ConcepTest 15.6

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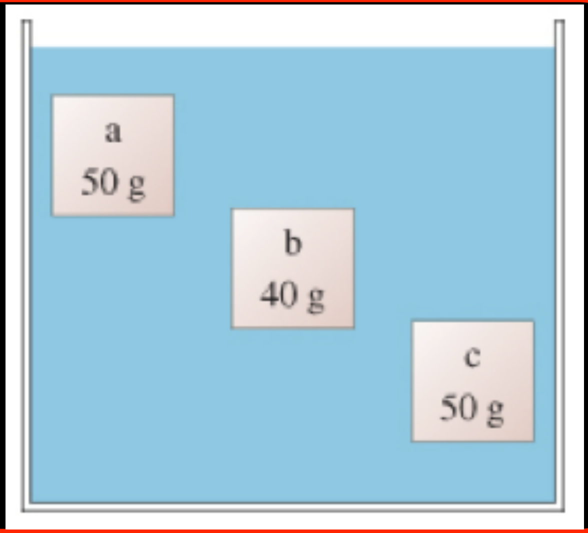
All 3 have same volume



From high to low:

(1) a,b,c

(2) c,b,a

(3) All are equal

(4) b,c,a

(5) a,c,b

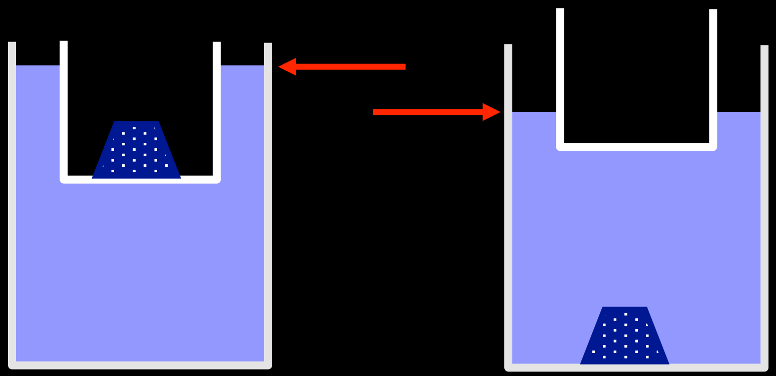
Archimedes' principle states that the buoyant force on an object is equal to the weight of the fluid displaced by the object. Each object displaces exactly the same amount of fluid since each is the same volume. So the buoyant force on all three objects is the same. Note that the buoyant force does not depend on the mass or location of the object.

ConcepTest 15.7 *(Pre)* On golden pond

A boat carrying a large chunk of steel is floating on a lake. The chunk is then thrown overboard and sinks. What happens to the water level in the lake (with respect to the shore)?

1) rises
2) drops
3) remains the same
4) depends on the size of the steel

ConcepTest 15.7 On golden pond



(1) rises

(2) drops

(3) remains the same

(4) depends on the size of the steel

Initially the chunk of steel "floats" by sitting in the boat. The buoyant force is equal to the **weight** of the steel, and this will **require a lot of displaced water** to equal the weight of the steel.

When thrown overboard, the steel sinks and **only displaces its volume in water**. This is not so much water -- certainly less than before -- and so the water level in the lake will drop.

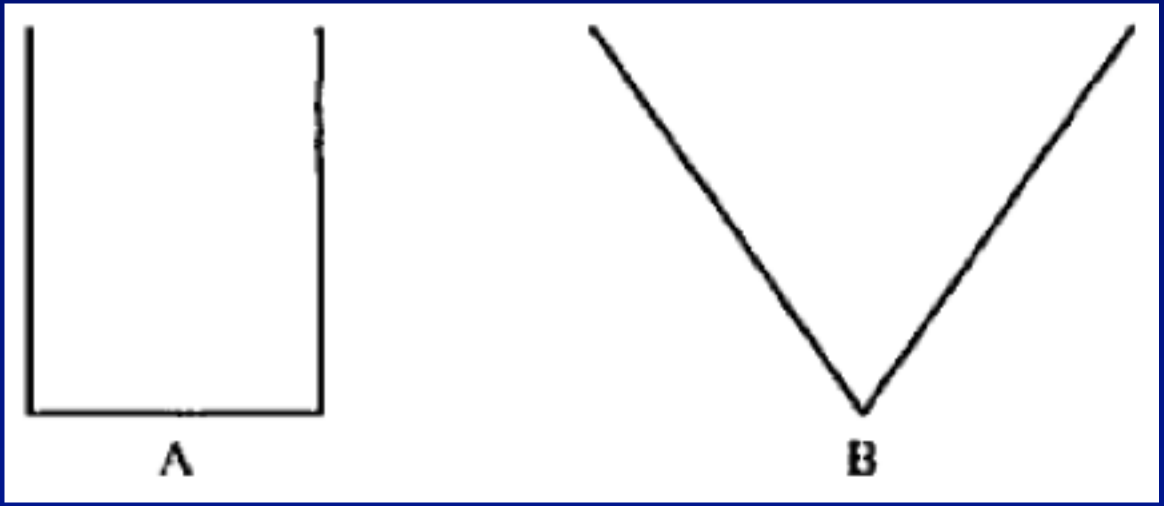
Ponderable:Bathroom scale in a pool

Suppose that you stand on a bathroom scale that is at the bottom of a swimming pool. The water comes up to your waist. Is the scale reading your weight? If not, does the scale read more or less than your weight? Explain.

Ponderable: Ship shape

Ships A and B have the same height and the same mass. Their cross-sectional profiles are shown in the figure. Does one ship ride higher in the water (more height above the water line) than the other? If so, which one? Explain.

Why are ships shaped like B and not A?



Ponderable: How lean are you?

- The body of a 75.7-kg person contains 0.0150 m3 of body fat.
- If the density of fat is 880 kg/m3, what percentage of the person's body weight is composed of fat?

  - If the person is weighed fully submerged in a pool, will he appear lighter or heavier? By how much will the reading on the scale change due to his body fat .