Physics 131- Fundamentals of Physics for Biologists I

Professor: Arpita Upadhyaya

- Pressure
- Buoyancy
- Flow

Foothold ideas: Pressure 2

- A constrained fluid has an internal pressure –like an internal force at every point in all directions. (Pressure has no direction.)
- At a boundary or wall, the pressure creates a force perpendicular to the wall. $\vec{F} = p\vec{A}$
- The pressure in a fluid increases with depth. (N0, N2)

$$p = p_0 + \rho g d$$

- The pressure in a fluid is the same on any horizontal plane no matter what the shape or openings of the container. (Vessel shaped like Utah.)

Foothold ideas: Buoyancy

- ***Archimedes' principle***: When an object is immersed in a fluid (in gravity), the result of the fluid's pressure variation with depth is an upward force on the object equal to the weight of the water that would have been there if the object were not.
- As a result, an object whose density is less than that of the fluid will float, one whose density is greater than that of the fluid will sink.
- An object less dense than the fluid will float with a fraction of its volume under the fluid equal to the ratio of its density to the fluid's density.

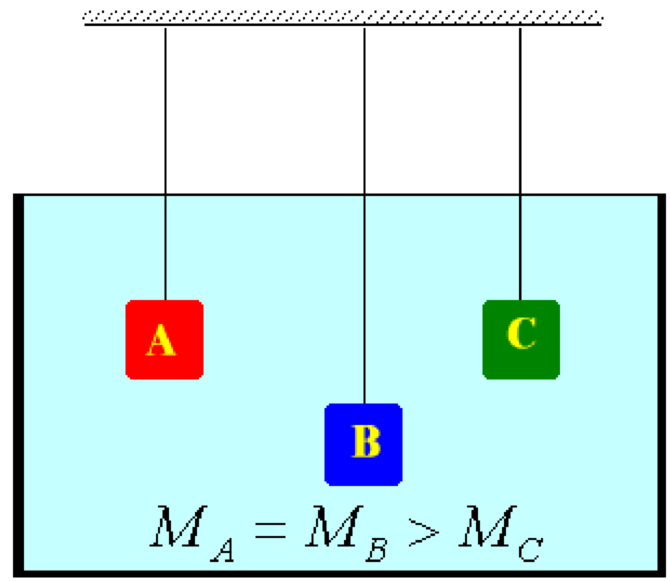
An object hung from a spring scale is lowered into water. When the object is immersed, the scale will read

1. a larger value
2. a smaller value
3. the same value
4. can’t tell – not enough info

DEMO

Three cubes of equal volume are hung on strings. A and B have the same mass and block C has less. The blocks are lowered into a fish tank and they hang at rest as shown.

How do the buoyant forces exerted by the water on the three cubes rank?



A. $BF_B > BF_A = BF_C$
B. $BF_B = BF_A > BF_C$
C. $BF_B > BF_A > BF_C$
D. $BF_A = BF_B = BF_C$
E. Some other ranking

Buoyancy

Example: Wood sphere in water

Weight of the wood:

$\mathbf{F}_g = -\rho_{Wood} V \mathbf{g}$

The fluid "provides" as much buoyant force as the weight of fluid pushed out of the way

$\mathbf{F_B} = \rho_{fluid} V \mathbf{g}$

Net force on wood:

$\mathbf{F_{net}} = \rho_{fluid} V \mathbf{g} - \rho_{Wood} V \mathbf{g} = (\rho_{fluid} - \rho_{Wood}) V \mathbf{g}$

Buoyancy and Flotation

A submerged object displaces its own **volume** of liquid

A floating object displaces its own **weight** in liquid (displaces liquid equal to its own weight)

Fraction of object submerged is equal to the **ratio** of the object’s density to that of the fluid

A boat carrying a large boulder is floating on a lake. The boulder is thrown overboard and sinks. The water level in the lake (with respect to the shore)

1. rises.
2. drops.
3. remains the same.

Buoyancy

V_{ice} is the total volume of the ice

V_{water} is the volume of the water displaced

– Equal to the volume of the ***submerged fraction of the iceberg*** (89% of the ice is below water)

$V_{water}=0.89*V_{ice}$

Buoyancy force: $\rho_{water}V_{water}\mathbf{g}$

= Weight of iceberg: $\rho_{ice}V_{ice}\mathbf{g}$

$\rho_{water}V_{water}\mathbf{g} = \rho_{ice}V_{ice}\mathbf{g}$

$\rho_{water*}*0.89*V_{ice} = \rho_{ice}V_{ice}$

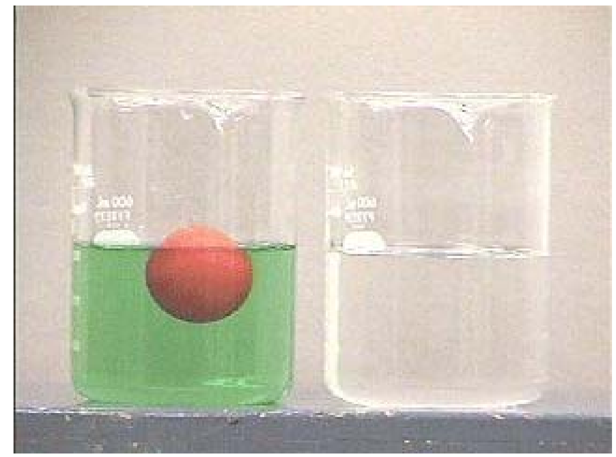
$\rho_{water}*0.89 = \rho_{ice}$

Which of the following is true for a ten-ton ship floating in salt water compared to floating in fresh water?

A) The buoyant force is greater in the salt water, and there is more salt water displaced
B) The buoyant force is greater in the salt water, and there is less salt water displaced
C) The buoyant force is less in the salt water, and there is less salt water displaced
D) The buoyant force is less in the salt water, and there is more salt water displaced
E) The buoyant force is the same in salt water and fresh water, but there is more salt water displaced
F) The buoyant force is the same in salt water and fresh water, but there is less salt water displaced

A ball floats in a beaker of water. The ball sinks in a beaker of mineral spirits. The mineral spirit will float above the water when poured slowly on top of water.

If the ball is floating on the water 2/3 of the way under the water, what will happen to the ball when mineral spirits is slowly poured on top of the water?



Relative to the top of the water,

A. The ball will go down.

B. The ball will go up.

C. The ball will stay at the same level.

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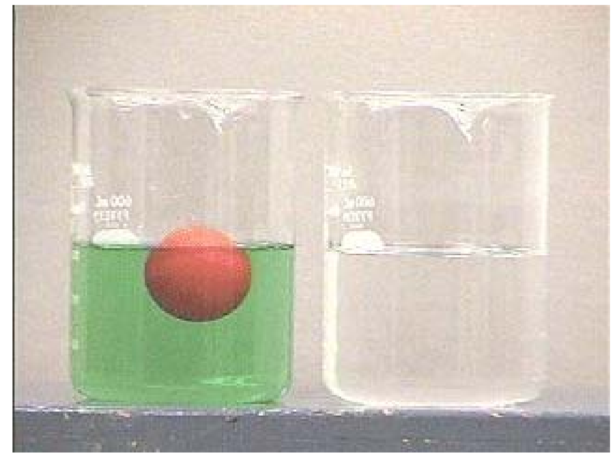

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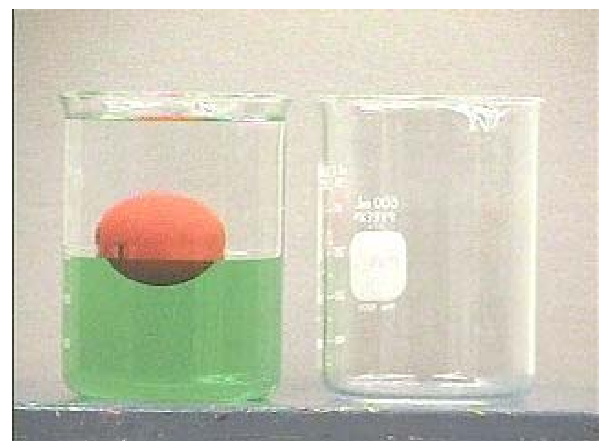


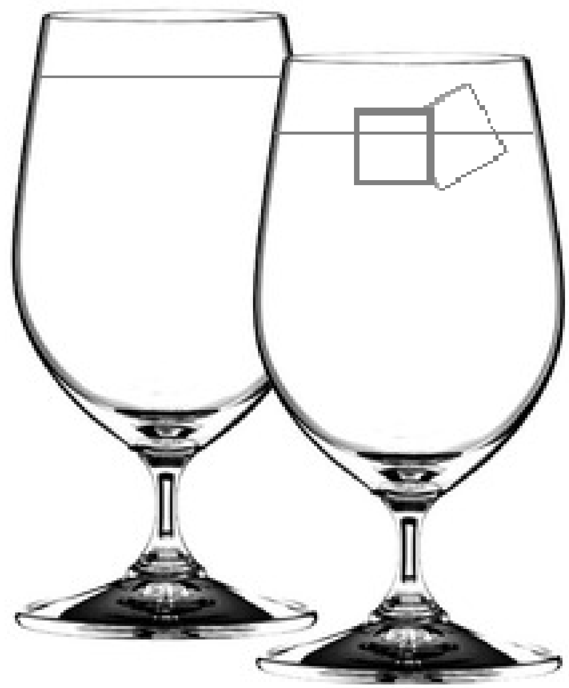
Two identical glasses are filled to the same level with water. One of the two glasses has ice cubes floating in it. Which glass weighs more?

A. The glass without ice cubes.

B. The glass with ice cubes.

C. The two weigh the same.

D. There is not enough in



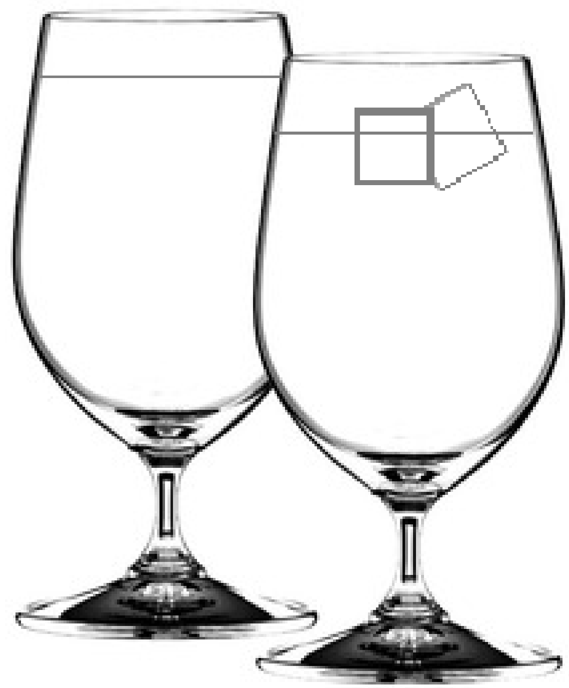
Two identical glasses are filled to the same level with water. One of the two glasses has ice cubes floating in it. When the ice cubes melt, in which glass is the level of the water higher ?

A. The glass without ice cubes.

B. The glass with ice cubes.

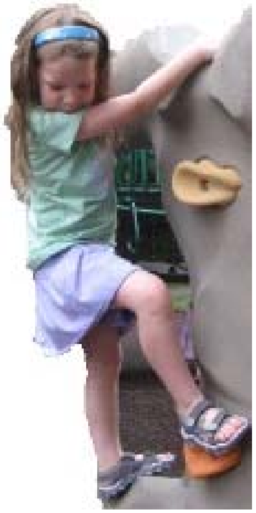
C. It is the same in both.

D. There is not enough informa



Surface tension

Foothold ideas: Surface tension



- Due to the intermolecular interactions holding a liquid together, the surface of a liquid experiences a tension.
- The pull across any line in the surface of the liquid is proportional to the length of the line.

$$F_{\text{surface tension}} = \gamma L$$

A bursting water balloon

Movie
https://www.youtube.com/watch?v=cZ5Az9WuYgI&noredirect=1

A bursting water balloon

Movie

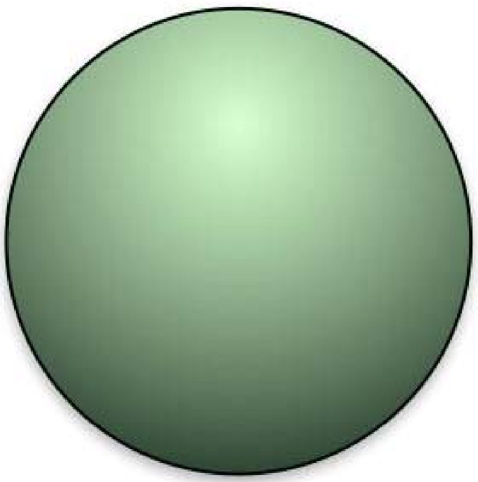
Two balloons are connected by a pipe with a valve. When the valve is opened, what will happen?

A. The big balloon will grow and the small balloon will get smaller.
B. The two balloons will equalize in size.
C. The small balloon will grow and become the bigger balloon.

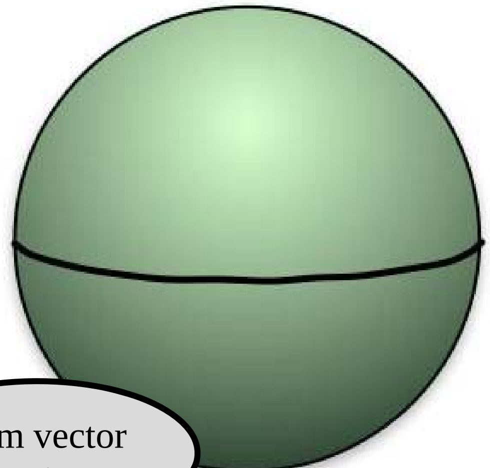
http://lecdem.physics.umd.edu/images/OldDemoIndex/demosf3/f3-02.htm

Laplace Bubble Law

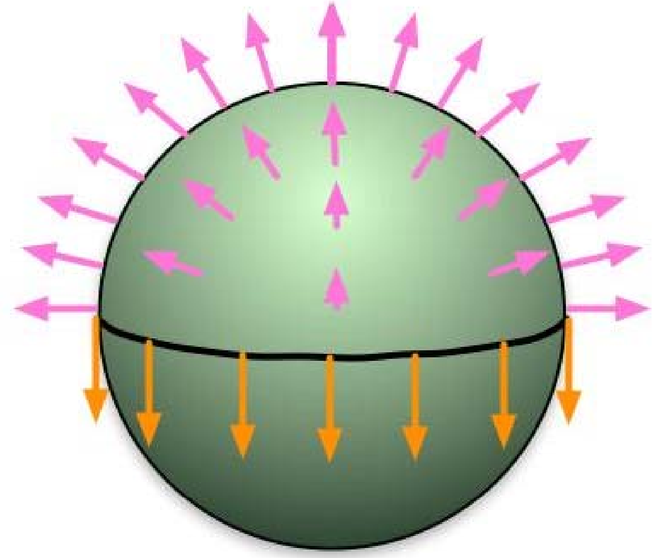
Consider a bubble



Now consider its top half



What forces act on it?



From vector averaging

$$F^{\uparrow}_{\text{air pressure inside}\rightarrow\text{top half}} = \tfrac{1}{2}\,pA = \tfrac{1}{2}\,p(2\pi r^2) = \pi p r^2$$

$$F^{\downarrow}_{\text{s.t. of bot half}\rightarrow\text{top half}} = \gamma L = \gamma(2\pi r) = 2\pi\gamma r$$

$$p = \frac{2\gamma}{r}$$

SMALLER bubble has bigger pressure!

Force from pressure inside (up) must cancel pull of surface tension from the bottom half (down)