Next quiz: Sections 9.3, 9.5, 9.6 and density
May need P = F/A again

Main Ideas Today:
Pressure with depth
Buoyancy

When a dense object (or any object) pushes against you, it applies pressure (or stress).

Pressure = Force / Area

Unit of pressure is **pascal** (Pa) $1\ \text{Pa} = 1\ \text{N/m}^2$

Pressure depends on the area over which the force is spread

(Also known as stress in solid materials, as in section 9.10.)

Pressure & Depth

- Assume the density is the same throughout the fluid

- Fluids have pressure that varies with depth

Reminder: P = Force / Area

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- If a fluid is at rest in a container, all portions of the fluid must be in static equilibrium $\sum \vec{F} = 0$

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  - Otherwise, the fluid would move (not equilibrium)

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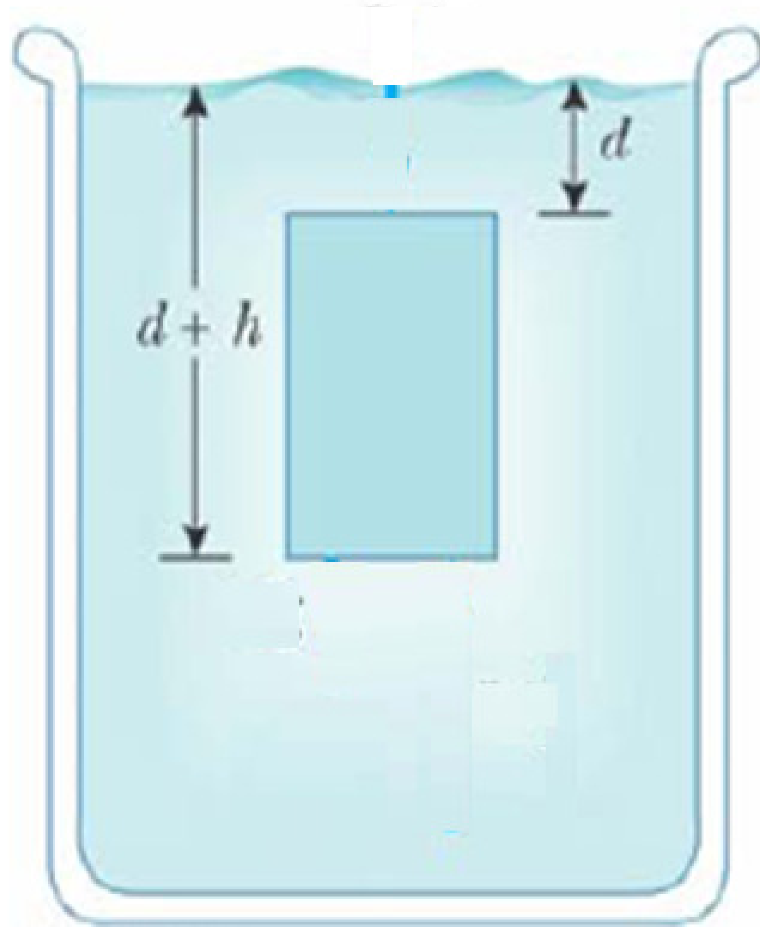
- Examine the darker region, a sample of liquid within a cylinder
  - It has a cross-sectional area *A*
  - Extends from depth *d* to *d* + *h* below the surface



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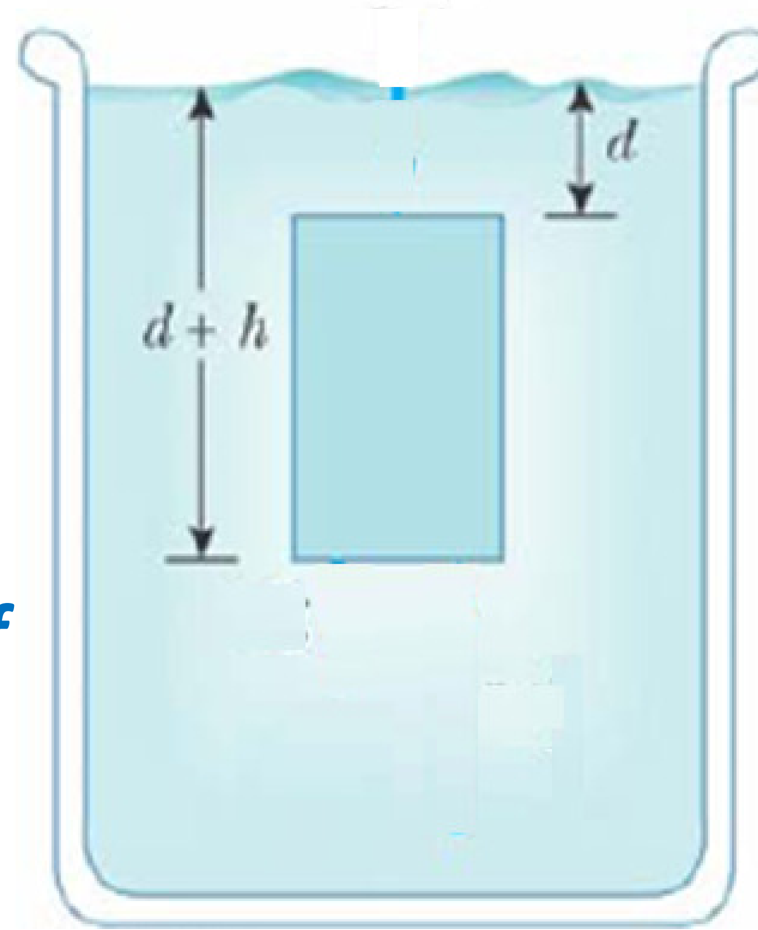
Area *A* coming out at you *(hidden)*

What forces act on this box of liquid?

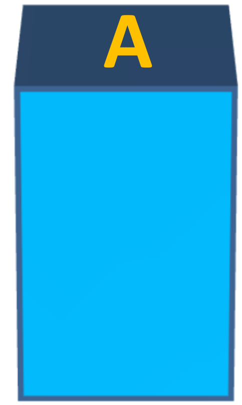


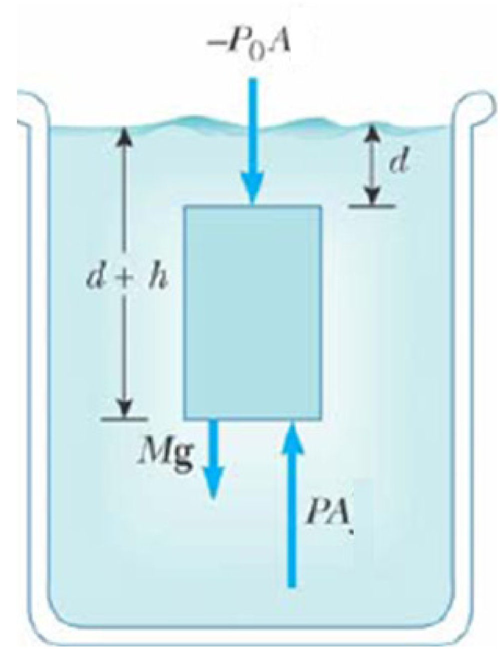
Reminder: P = Force / Area

Pressure & Depth

$$P = F/A \text{ or } F=PA$$

- The three forces are: ***(vertical direction)***





  - Gravity acting downward, $M\mathbf{g}$

Pressure & Depth

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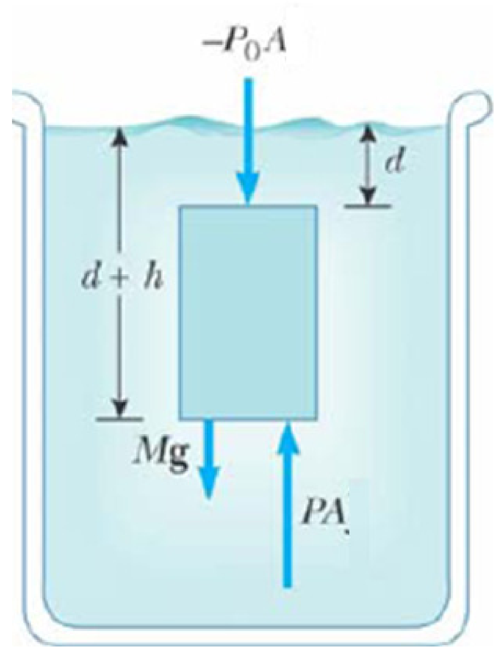


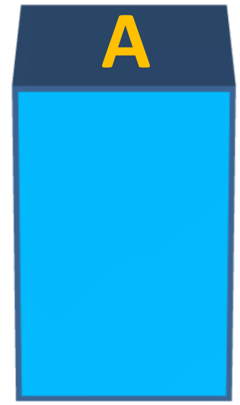
- The three forces are: *(vertical direction)*
  - Downward force on the top, P_0A
  - Upward on the bottom, PA
  - Gravity acting downward, $M\mathbf{g}$

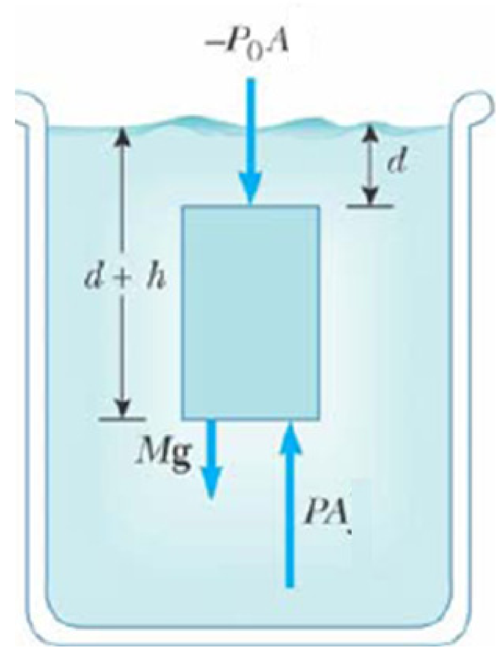
- Since the net force must be zero:
  - This chooses upward as positive

$$\Sigma F_y = 0 = PA - P_oA - Mg$$

Pressure & Depth

P = F/A or F=PA





- The three forces are: *(vertical direction)*
  - Downward force on the top, P_0A
  - Upward on the bottom, PA
  - Gravity acting downward, $M\mathbf{g}$
    - The mass can be found from the density: $M = \rho V = \rho A h$

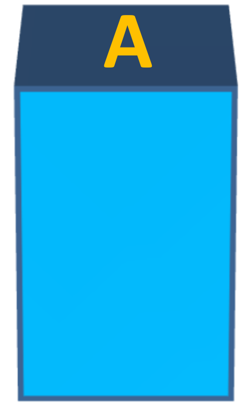
- Since the net force must be zero:
  - This chooses upward as positive

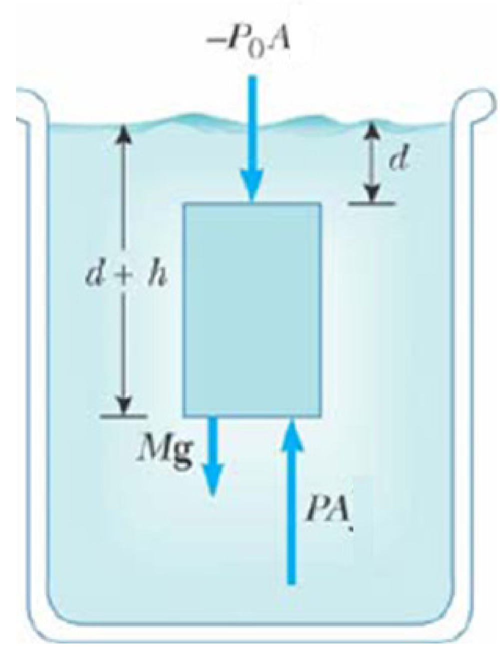
$$\Sigma F_y = 0 = PA - P_oA - Mg$$

$$0 = PA - P_oA - \rho A h g$$

Pressure & Depth

P = F/A or F=PA





- The three forces are: *(vertical direction)*
  - Gravity acting downward, $M\mathbf{g}$
- Since the net force must be zero:
  - This chooses upward as positive
- Solving for the pressure gives
  - $P = P_0 + \rho gh$
- The pressure P at a depth h below a point in the liquid at which the pressure is P_0 is greater by an amount ρgh

$$\Sigma F_y = 0 = PA - P_oA - Mg$$

$$0 = PA - P_oA - \rho Ahg$$

Pressure at Bottom of Lake

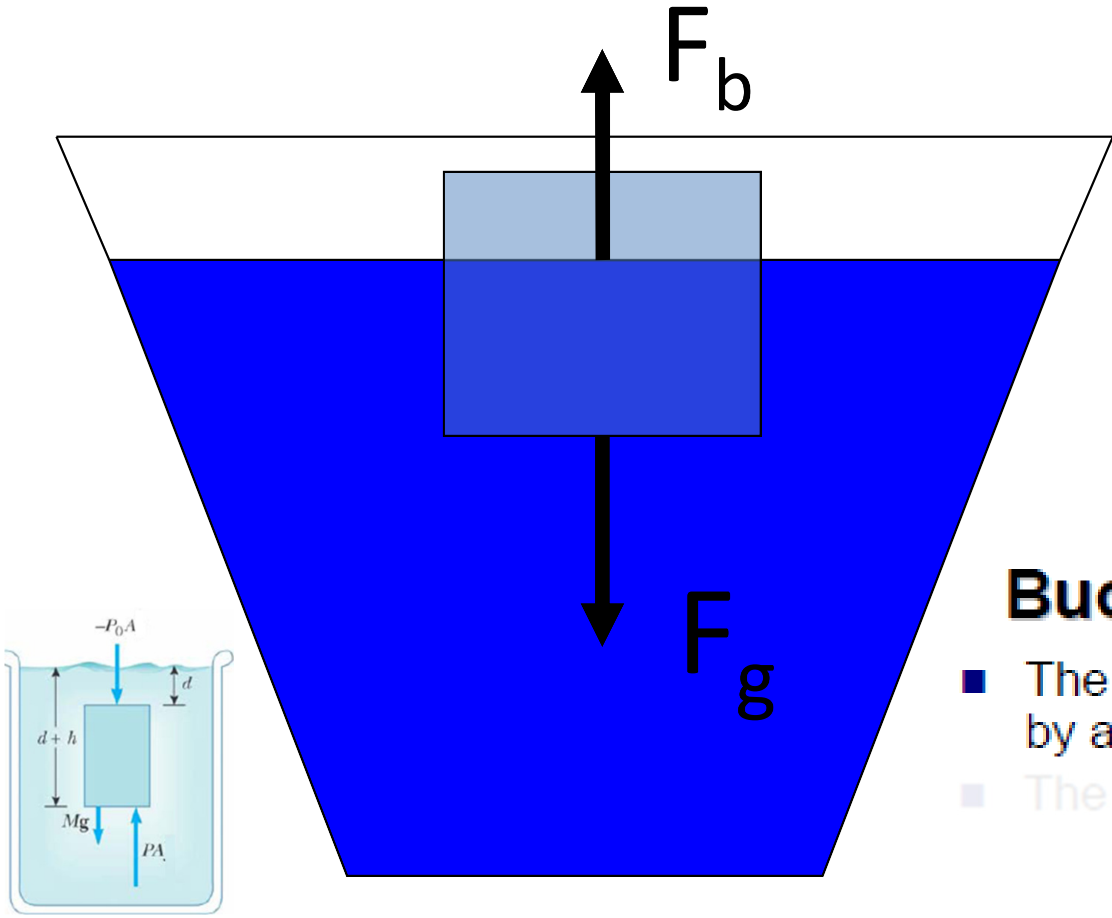
Calculate the absolute pressure at the bottom of a freshwater lake at a depth of 27.5 m. Assume the density of the water is 1000 kg/m^3 and the air above is at a pressure of 101.3 kPa.

Good Ideas Come To You When Relaxed

- https://www.youtube.com/watch?v=ijj58xD5fDI

Archimedes' Principle

If the weight of the displaced fluid equals the weight of the object, the object floats.



$$F_b = F_g$$

Floating Object Only

Buoyant Force

- The **buoyant force** is the upward force exerted by a fluid on any immersed object
- The parcel is in equilibrium

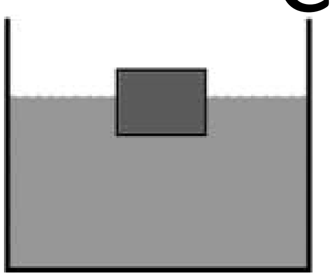
$$F_b = W_{FluidDisplaced}$$

Any object <u>completely or partially</u> submerged in a fluid is buoyed up by a force equal to the weight of the fluid displaced.

Two blocks (A and B) have the same size and shape. Block A floats in the water, but Block B sinks in the same water. Which block has the larger buoyant force on it?

$$F_b = W_{FluidDisplaced}$$

A. Block A has the larger buoyant force on it.
B. Block B has the larger buoyant force on it.
C. Neither; they have the same.
D. Not enough information



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Archimedes's Principle

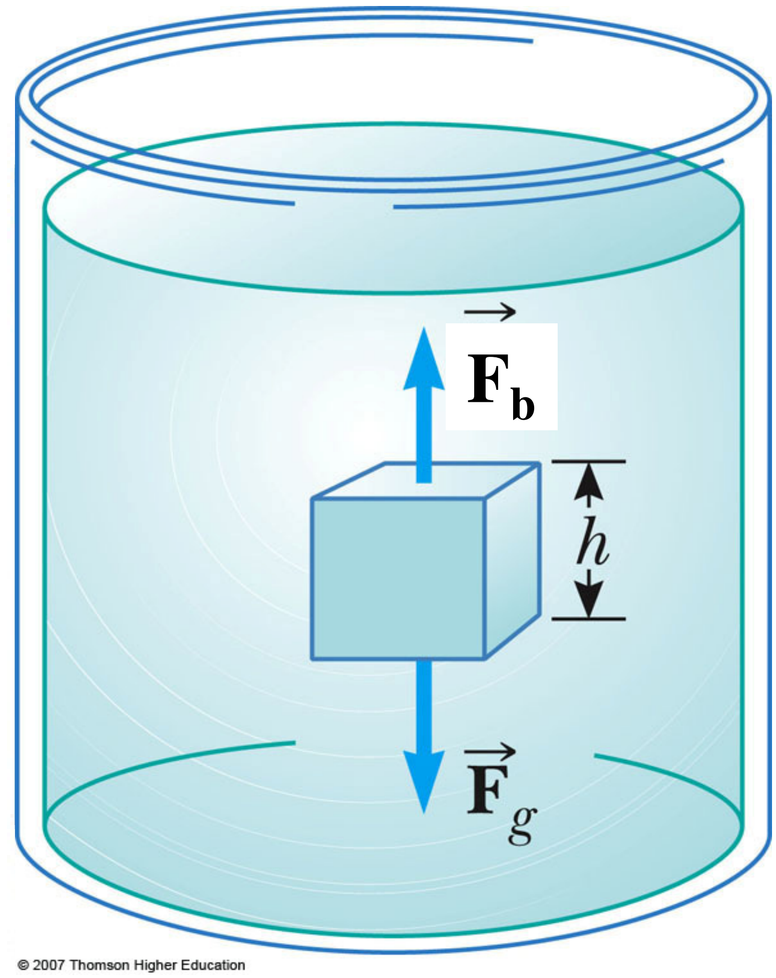
$$\rho = M / V$$

- The magnitude of the buoyant force always equals the weight of the fluid displaced by the object $F_b = M_{WaterDisplaced}\, g = \rho_{fluid}\, g V$
- Archimedes's Principle does not refer to the makeup of the object experiencing the buoyant force

Two ways to find F_B

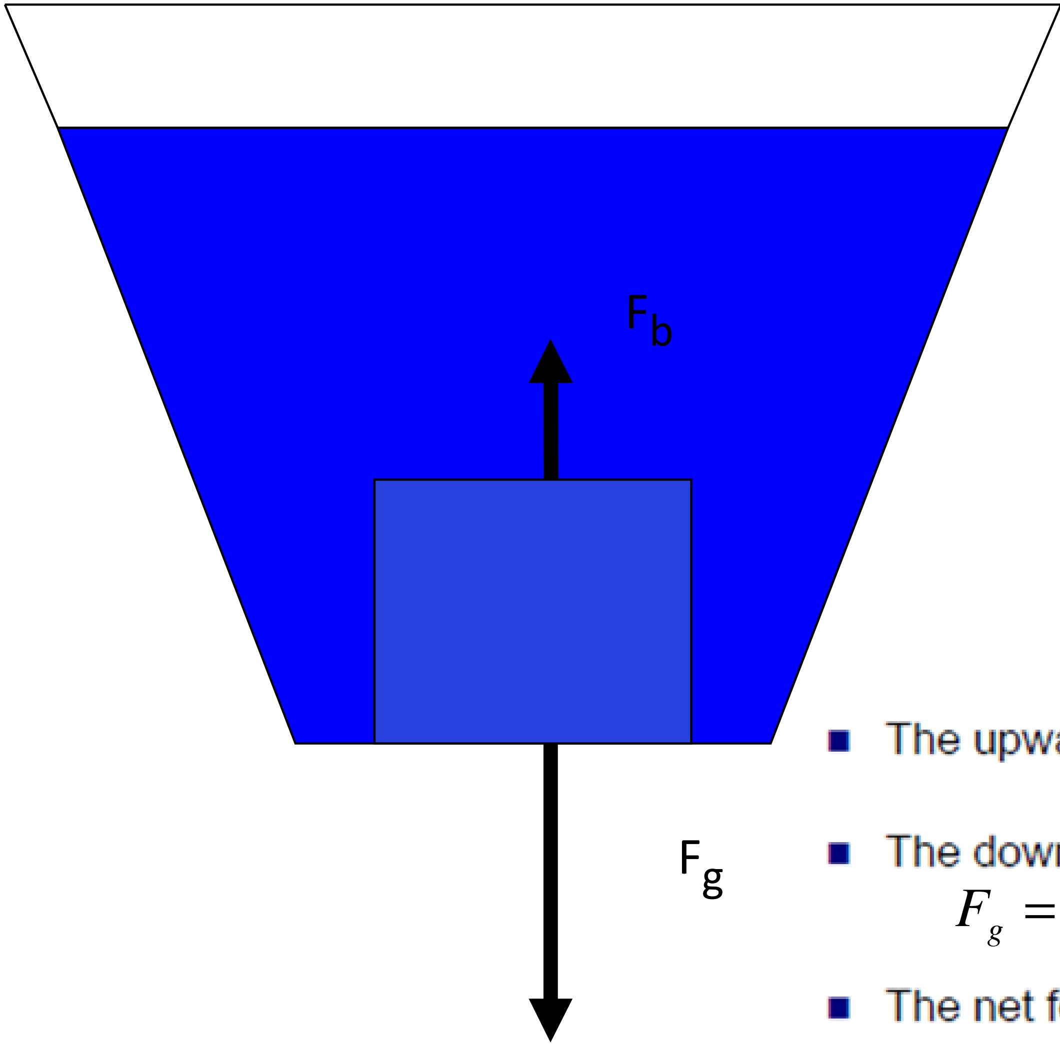
As stated before:

$$F_b = (P_b - P_t)A = \rho_{fluid} V . g$$



If the weight of the displaced water is less than the weight of the object, the object sinks.

Therefore, if the average density of the object is more than the density of water, it sinks.

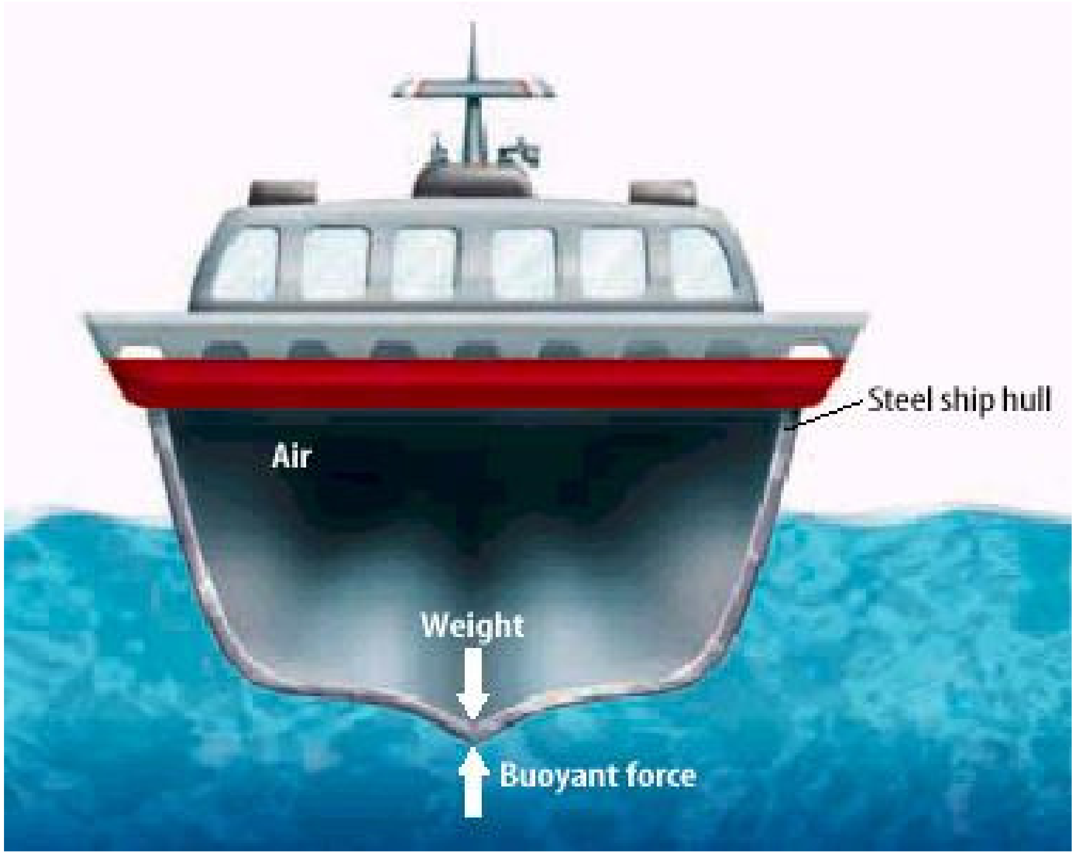


$F_g > F_b$

Object sinks

- The upward buoyant force is $F_b = \rho_{fluid} g V = \rho_{fluid} g V_{object}$
- The downward gravitational force is $F_g = \rho_{object} g V_{object}$
- The net force is $F_b - F_g = (\rho_{fluid} - \rho_{object}) g V_{object}$

How can a steel ship float?



The hull contains mostly air and displaces a lot of water...enough so that $F_b = F_g$ and it floats.

Summary for a **Floating Object**

- Object in equilibrium
- Buoyant force is balanced by force of gravity
- Volume of the <u>fluid displaced</u> corresponds to volume of the object beneath the fluid level

$$F_b = F_g$$

$$\rho_{fluid} g V_{fluid} = \rho_{object} g V_{object}$$

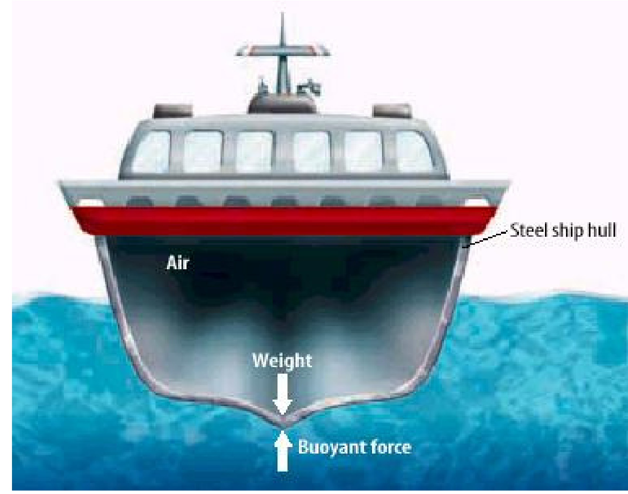
% submerged

$$\frac{V_{fluid}}{V_{object}} = \frac{\rho_{object}}{\rho_{fluid}}$$

Archimedes's Principle, *Iceberg Example*

- What fraction of the iceberg is below water?

Past Homework
Floating Object



The average human has a density of 945 kg/m^3 after inhaling and 1020 kg/m^3 after exhaling. Without making any swimming movements, what percentage of the human body would be above the surface in the Dead Sea (a lake with a water density of about 1230 kg/m^3) after inhaling and after exhaling?

$$\frac{\rho_{fluid}}{\rho_{object}} = \frac{V_{object}}{V_{fluid}}$$

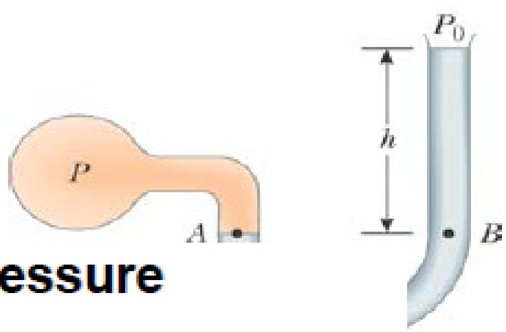
You hold a 0.54 kg rubber ball with a diameter of 25 cm just below the water's surface in your swimming pool. With what force do you have to apply to keep the ball from popping back up above the water?

Density of freshwater = 1000 kg/m^3

Pressure Measurements:

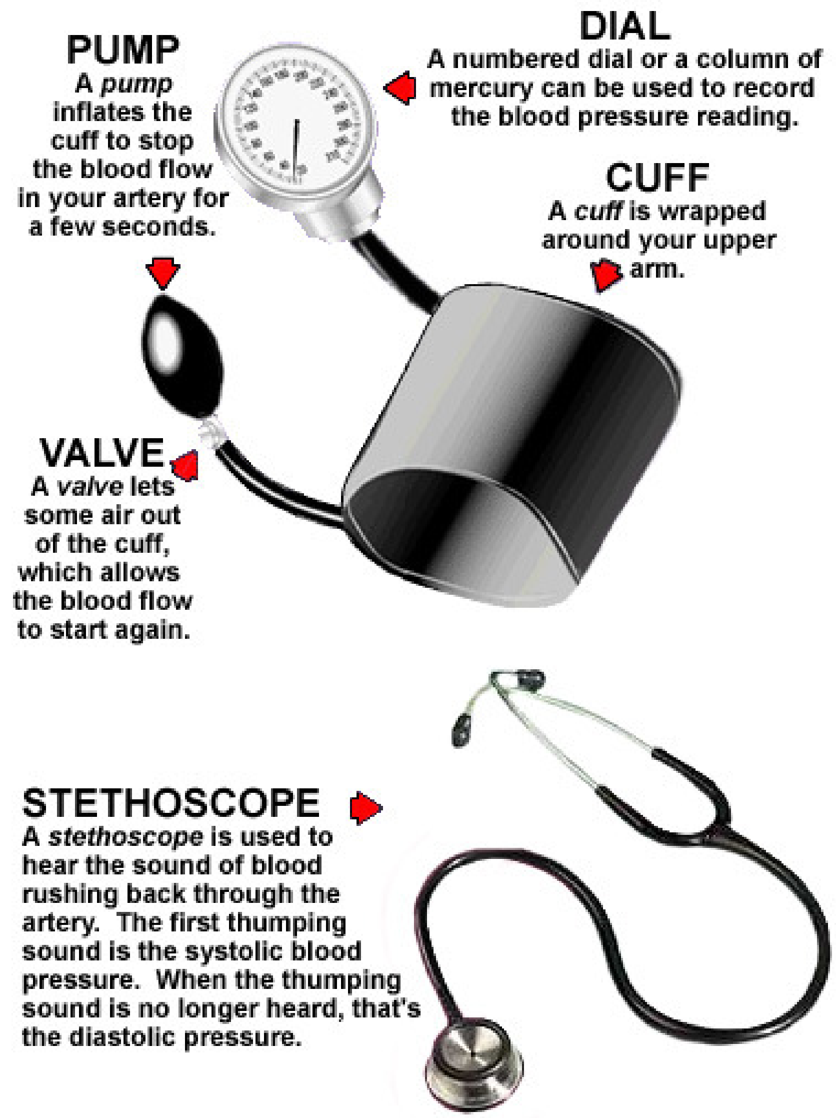
Manometer

- A device for measuring the pressure of a gas contained in a vessel
- One end of the U-shaped tube is open to the atmosphere
- The other end is connected to the pressure to be measured
- Pressure at B is $P_0 + \rho gh$



Absolute vs. Gauge Pressure

- $P = P_0 + \rho gh$
- P is the **absolute pressure**
- The **gauge pressure** is $P - P_0$
  - This is also ρgh
  - This is what you measure in your tires



Not on test

Clicker Answers

123=D, 124=B