Spring 2014

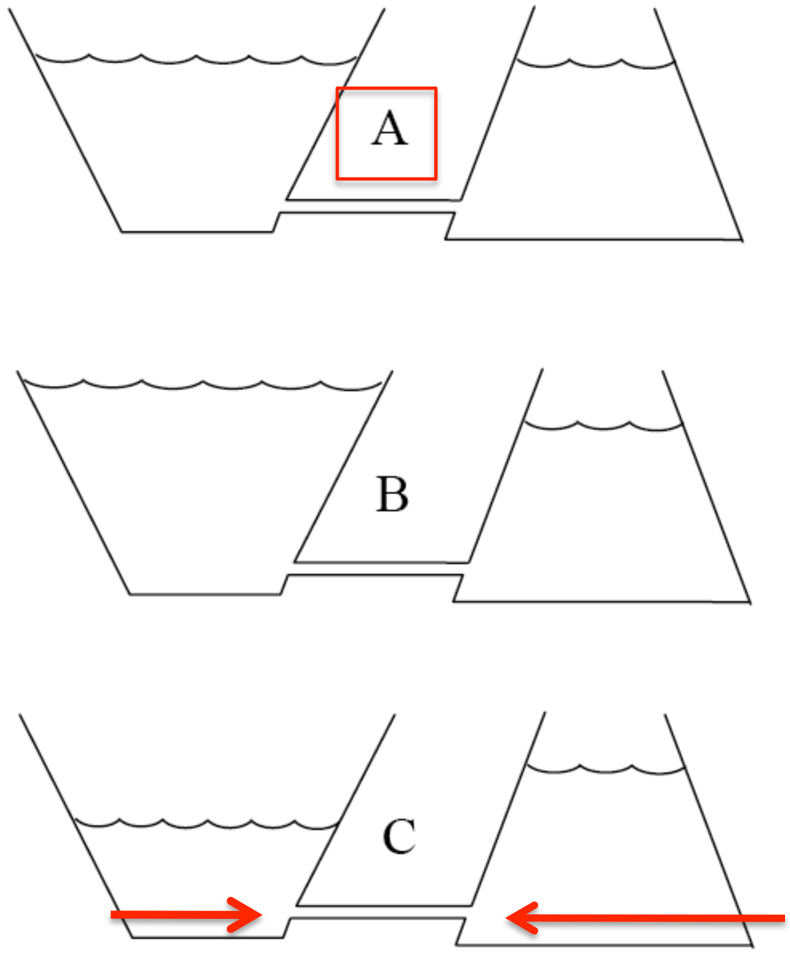
PHYS-2010

Lecture 41

Clicker Question

Room Frequency BA

As shown, two containers are connected by a hose and are filled with water. Which picture correctly depicts the water levels?



Different depths would give different pressures! The net force on the fluid at the connection tube would not be zero and there would be flow!

$$P = P_{atm} + \rho g h$$

Fluid Level Vessels Demo

Announcements

- Finish Giancoli **Chapter 10** and start **Chapter 11.**
- **Last Written Homework # 10** due today, April 25, at 4 pm.
- Special **Study Session** by Prof. Pollock and Rosemary Wulf, Tuesday, April 29, 5-6 pm in G125.
- **Next week** in sections: Review Recitation and Lab makeup (Labs 4-8). Attendance required.
- **Final Exam:**
  - Monday, May 5, 1:30-4:00, in G1B30.
  - Cumulative, but with more focus on last chapters.

Water Pressure as a Function of Depth

$$P_h = P_{atm} + \rho_{Water} h g$$

Pressure only depends on the depth; at a given depth the pressure is the same.

Water Pressure

At the surface of a swimming pool, pressure is due to air: **P_{atm} = 1 atm.**

At what depth in the pool will the pressure be 2 atm?

$$P_h = P_{atm} + \rho g h \qquad \Rightarrow h = \frac{P_h - P_{atm}}{\rho g}$$

P_{atm} = 1 atm ~ 10^5 Pa

$$h = \frac{2\text{x}10^5\text{Pa} - 1\text{x}10^5\text{Pa}}{(1000\ \text{kg/m}^3)\ (10\ \text{m/s}^2)} \approx 10\ \text{m}$$

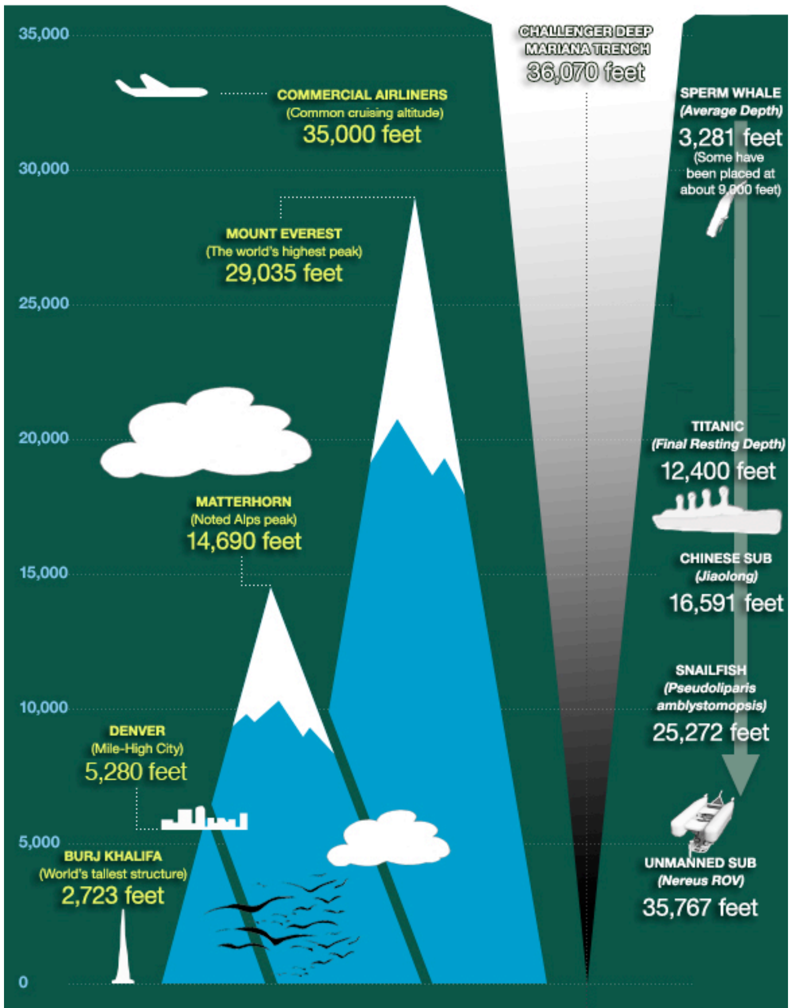
Pressure in ocean increases by 1 atm for every 10 m of depth!

Comment on terminology: often people leave out the P_{atm}, but if you want the *total, absolute* pressure, you must include it.

Gauge Pressure is the amount of pressure after subtracting P_{atm}.

Pressure in Water

Pressure in the ocean increases by 1 atm for every 10m of depth!



$$P_h = P_{atm} + \rho g h$$

$$P_h \approx 1\,\text{atm}\left(1 + \frac{h}{10\,\text{m}}\right)$$

- Deepest Place on Earth:
  Mariana Trench (≈ 11 km)

  \- near Guam in the Pacific Ocean.
- Pressure at the bottom of Mariana Trench: ≈ 1,100 atm !

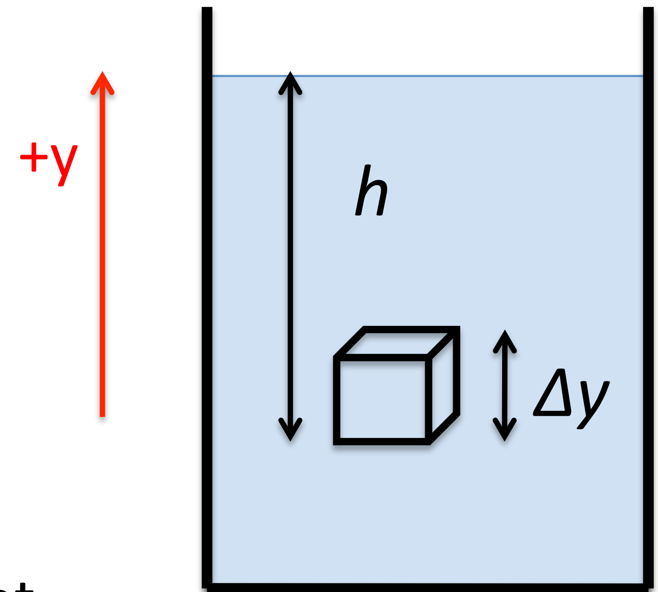
  (it's just crushing!)

Buoyancy

Forces on a Small Box of Water:

Consider again a small imaginary cubic box at depth *h.*

We argued that in static fluids, the net force on the box must be zero.



Again we conclude that the side forces all cancel and only the top and bottom forces are left.

$$F_{net} = F_{top} + F_{bottom} - m_{water}\, g = 0$$

Using our depth formula we can find that

$$F_{net} = -\rho_{Water} g(h - \Delta y)A + \rho_{Water} ghA - m_{Water} g = 0$$

$$\rho_{Water} g \Delta y A = m_{Water} g$$

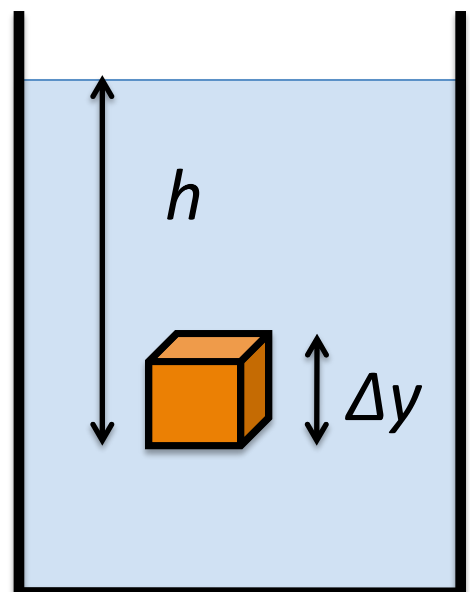
The pressure difference between top and bottom is just the weight of the water in the box

Forces on a Small Box of Gold

Now suppose the cubic box is a block of **gold** at depth *h*

The fluid outside the block is the undisturbed, so the pressures are not changed. The *net force however is no longer necessarily zero!!!*

The pressure difference between top and bottom is just the weight of the water in the box.



Using our depth formula we can find that

$$F_{\text{net}} = -\rho_{Water} g(h-\Delta y)A + \rho_{Water} ghA - m_{Gold} g =$$
$$= \rho_{Water} g\,\Delta y\,A - m_{Gold} g = m_{Water} g - m_{Gold} g$$

Water Pressure → $m_{Water} g$

Gravity on Gold → $m_{Gold} g$

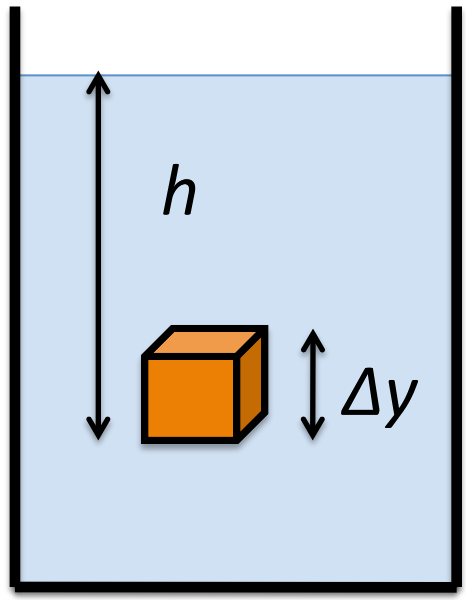
$$\rho_{Water} g \Delta y A = m_{Water} g$$

Buoyant Force

So we conclude that the net force is

$$F_{\text{net}} = \rho_{Water} g \Delta y A - m_{Gold} g = m_{water} g - m_{Gold} g$$

The fluid exerts an *upward* force of $m_{water}g$ on the gold cube.
This is known as the **buoyant force**.



For some general fluid:

$$F_{Buoyancy} = \rho_{Fluid} g \Delta y A = m_{Fluid} g$$

This is true for *any shape volume V!*

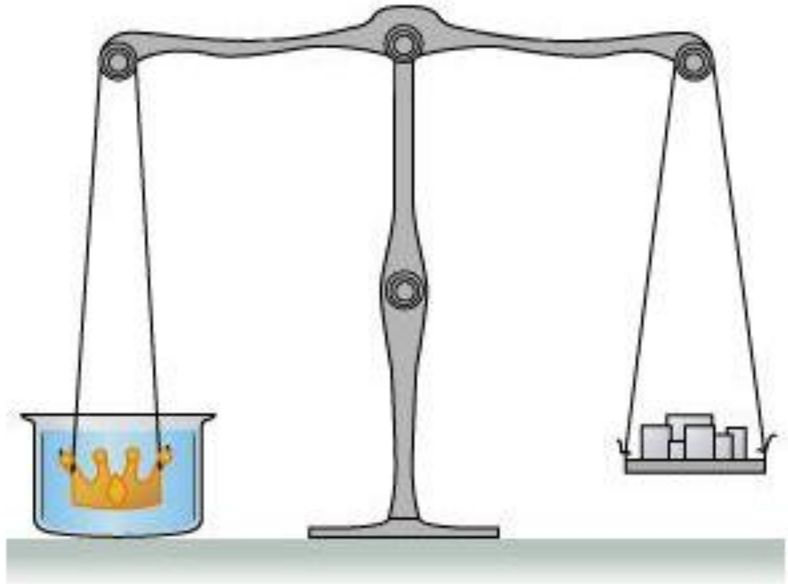
$$F_{Buoyancy} = \rho_{Fluid} g V = m_{Fluid} g$$

Archimedes Principle

A solid body, either partially or totally submerged in a fluid, will experience an upward **buoyant force** equal to the *weight* of the displaced fluid.

$$F_{Buoyancy} = \rho_{Fluid} g V = m_{Fluid} g$$

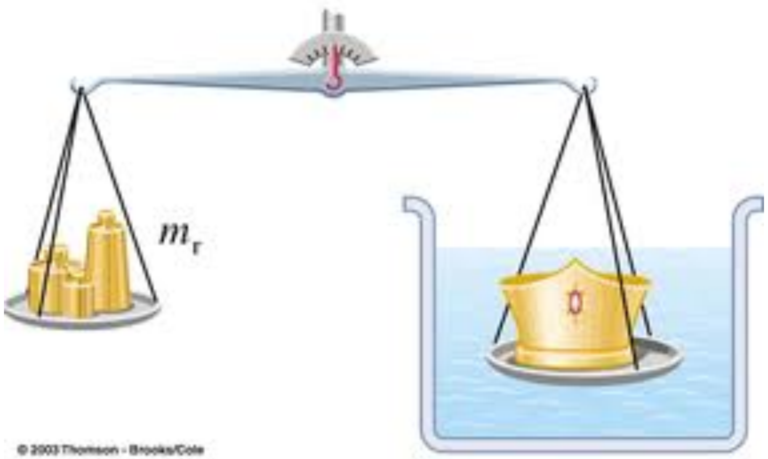
Archimedes' Crown Demo

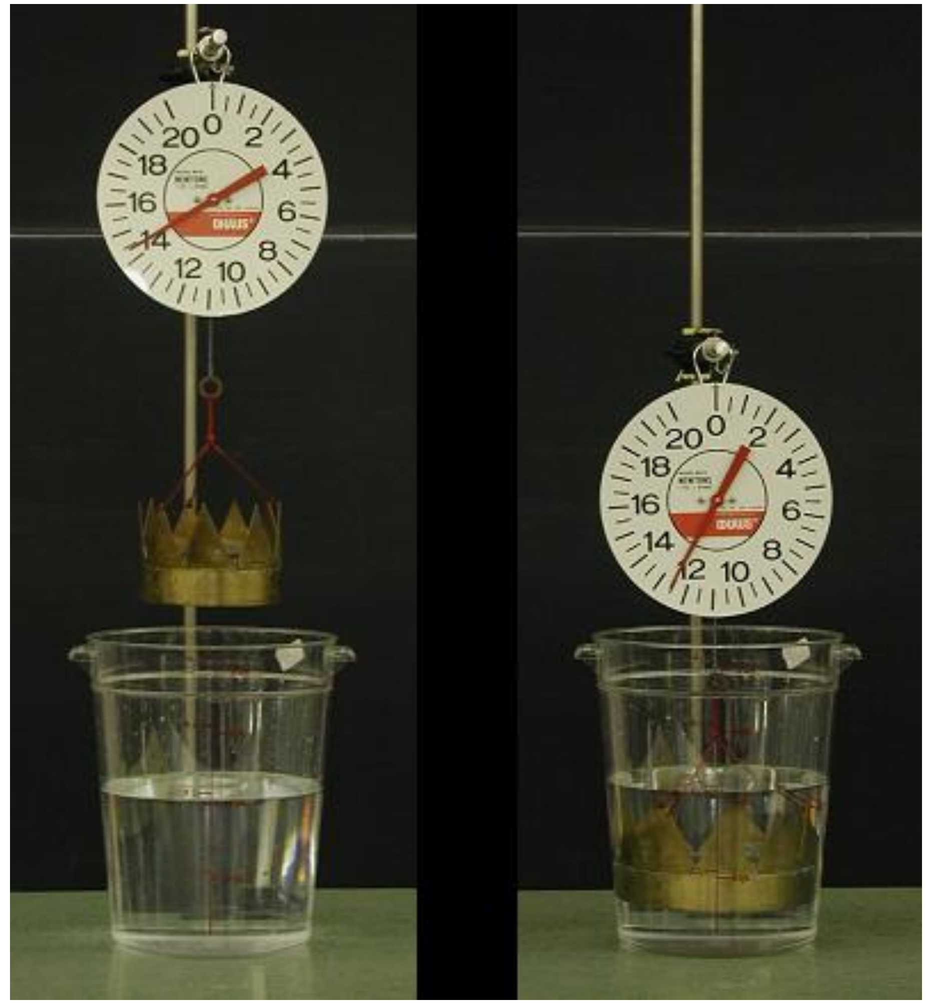


The crown and the gold have equal weight.

The crown displaced more water than the gold.

Archimedes' Crown Demo

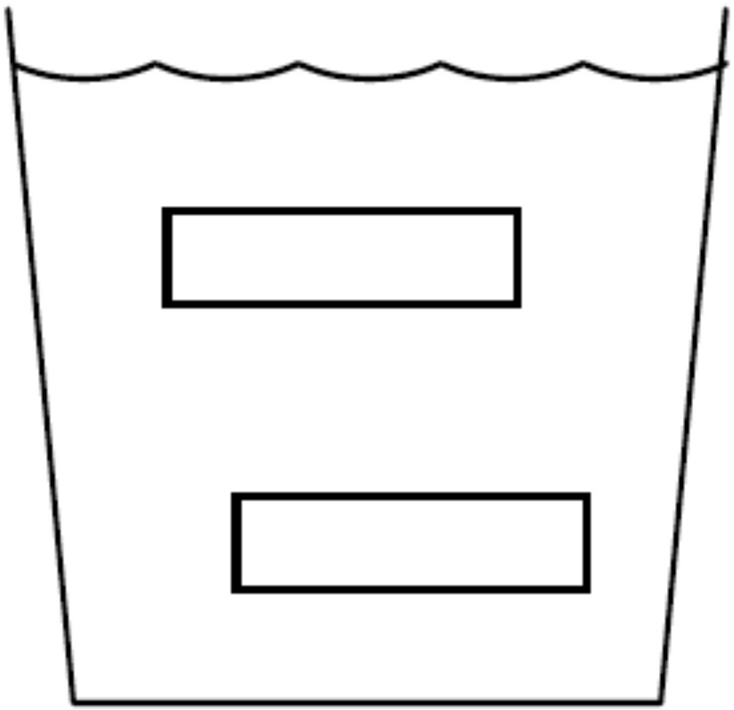




Clicker Question

Room Frequency BA

Two identical bricks are held under water in a bucket. One of the bricks is lower in the bucket than the other. The upward buoyant force on the lower brick is.....



A) greater

B) smaller

C) the same as

the buoyant force on the higher brick.

The weight of displaced fluid does not depend on depth

$$F_{buoy} = m_{fluid}g = \rho_{fluid}Vg$$

Clicker Question

Room Frequency BA

A solid piece of plastic of volume V and density $\rho_{plastic}$ would ordinarily float in water, but it is held under water by a string tied to the bottom of bucket as shown. (The density of water is ρ_{water}.)

What is the buoyant force on the plastic?

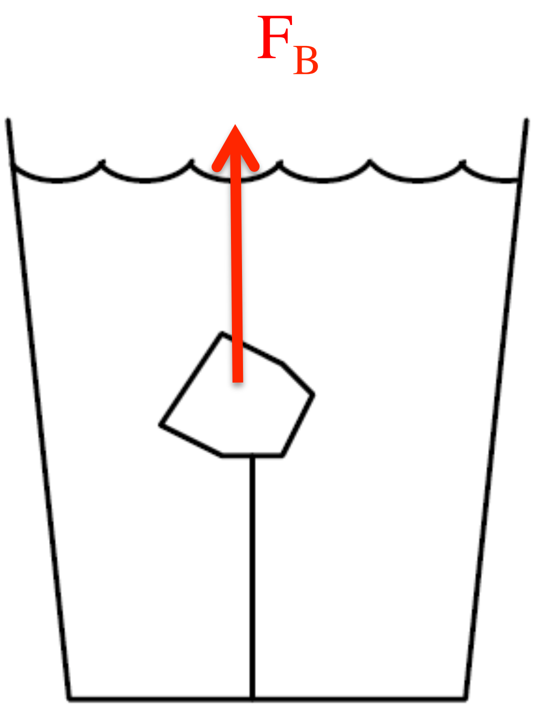
A) Zero

B) $\rho^{plastic}\ V$

C) $\rho^{water}\ V$

D) $\rho^{water}\ V\ g$

E) $\rho^{plastic}\ V\ g$



$$F_{buoy} = m_{fluid}\, g = \rho_{fluid} V g$$

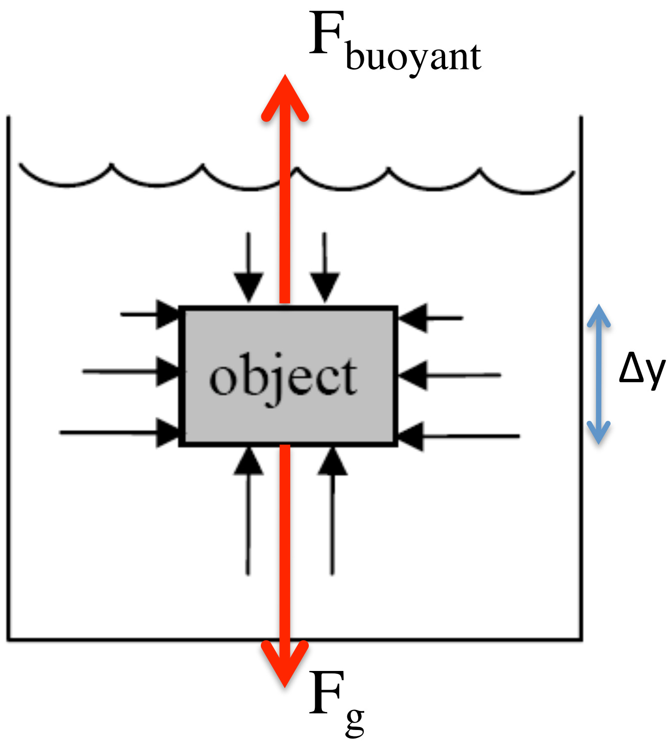
Motion of Submerged Objects: Sinking and Floating

When will an object sink or float?

$$F_{buoy} = m_{fluid}\, g$$

$$F_g = -\, m_{object}\, g$$

$$F_{net} = m_{Fluid}\, g - m_{Object}\, g$$



Object will rise: $F_{buoy} > |F_g|$ $(m_{fluid} > m_{object})$

Object will sink: $F_{buoy} < |F_g|$ $(m_{fluid} < m_{object})$

Object will be in equilibrium: $F_{buoy} = |F_g|$ $(m_{fluid} = m_{object})$

Motion of Submerged Objects: Sinking and Floating

Since F_{buoy} and F_g both depend on the ***same volume V***, we can also write

Object will rise: $\varrho_{fluid} > \varrho_{object}$

Object will sink: $\varrho_{fluid} < \varrho_{object}$

Object will be in equilibrium:

$$\varrho_{fluid} = \varrho_{object}$$