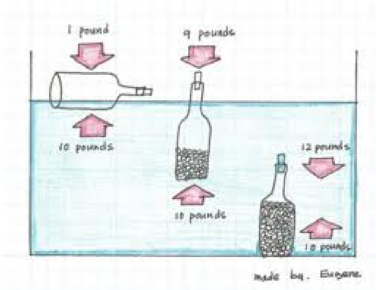
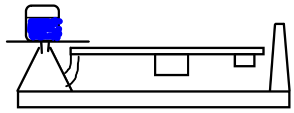
1.3 Buoyancy and Archimedes' Principle



1. Physics Democracy Part 1!

I am going to put my finger in the beaker of water (without chopping it off). Will the beam go up (heavier reading), go down (lighter reading), or stay the same (no apparent change of mass)?

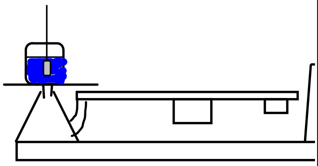


The Beam:

Goes Up (Heavier)	Goes Down (Lighter)	Stays Same

2. Physics Democracy Part 2!

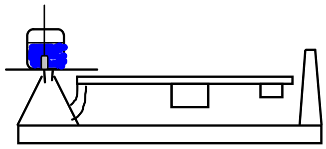
A 64.0 g lump of tin, with a volume of 8.5 cm^3 will be submerged in water (with the scale set at a neutral reading beforehand). The density of water is 1 g/cm^3. The change in the scale's reading is:



Zero Grams (Unchanged)	+ 8.5 grams	+ 64.0 g

3. Physics Democracy Part 3!

The same 64.0 g lump of tin will be lowered to rest on the bottom. The total change in the scale's reading is:



+ 8.5 g	+ 64.0 g	+8.5 + 64.0 g = 72.5 g	+ 64.0 g - 8.5 = 55.5 g

Buoyancy

Have you ever been close to drowning? It's because your buoyant force wasn't large enough!

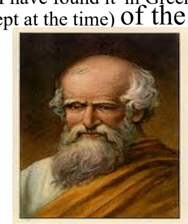
This is an upward force resulting from an object being wholly or partially immersed in a fluid.

The difference in height between the top and bottom of the object yields a pressure (P = F/A) difference(more pressure lower, less pressure higher).
The imbalance in pressure results in this force.

Note: in weightless conditions, things don't float!
In space, ice cubes are surrounded by the liquid they are put in (which won't stay in a glass); astronauts can't burp!

Archimedes

Archimedes of Syracuse was a Greek philosopher/ scientist tasked with determining whether the king's crown was pure gold, or an alloy.
Legend has it that the solution came to him during a bath, and he was so excited that he ran through the streets naked, shouting "Eureka!" ('I have found it' in Greek).
He measured the density (a new concept at the time) of the crown, and compared it to that of pure gold to make his judgment.



It is unknown whether the crown was pure gold or not.

Archimedes' Principle

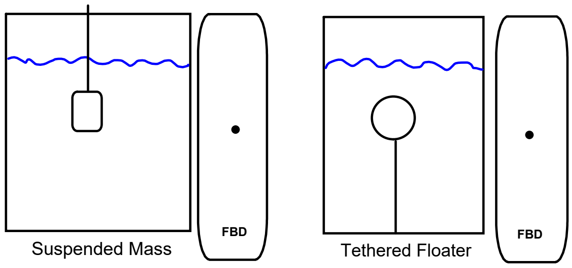
"A body immersed wholly or partially in a fluid experiences a buoyant force equal in magnitude to the weight of the volume of fluid displaced."

AP Equation	F_b = buoyant force (N) ρ_f = density of fluid (kg/m^3) V_f = volume of fluid displaced (m^3) g = 9.81 m/s^2
$F_b = \rho_f V_f g$	

Note, "f" is added to this equation.

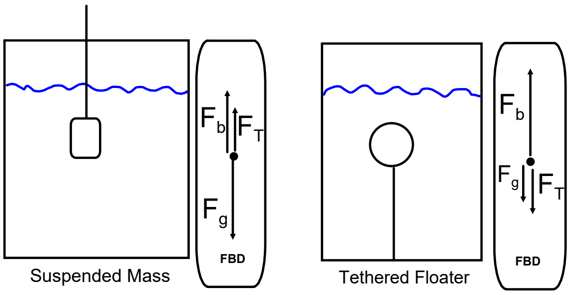
4. Review FBDs Page 1

Make free body diagrams for the following situations!
Remember: the dot is a nexus where forces emanate from.



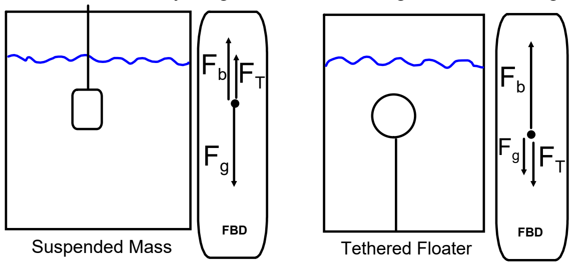
Review FBDs: Page 1 Answers

Force vectors always point away from the nexus.



FBD Relations: Page 1 Equations

From the free body diagrams, the following relations emerge:

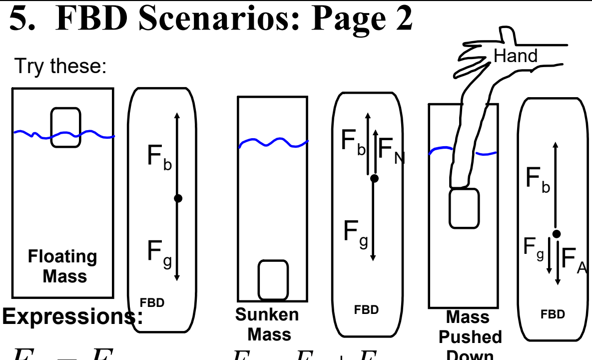


$$F_g = F_T + F_b$$

$$F_b = F_T + F_g$$

5. FBD Scenarios: Page 2

Try these:



Expressions:

$$F_g = F_b$$

$$F_g = F_N + F_b$$

$$F_g + F_{Applied} = F_b$$

6. Helium Balloon Example

A spherical helium balloon has a radius of 1.10 m. What is the buoyant force of the balloon in air?

The density of air is 1.29 kg/m^3

Helium Balloon Answer

Compute the balloon volume first, then use Archimedes' principle to solve:

Volume: $$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(1.10\,m)^3 = 5.58\,m^3$$

Buoyant force:

$$F_b = (\rho_{air} V_f)g = (1.29\,kg/m^3)(5.58\,m^3) \cdot 9.81\,m/s^2 = 70.5\,N$$

Buoyancy and Density

It is common to say that a helium balloon floats because it is 'lighter than air.' It's more accurate to say that it floats because it is *less dense* than air.

If an object is completely submerged in a fluid, where $V_f = V_o$, you can draw this relation for buoyant force:

$F_b = \left(\frac{\rho_f}{\rho_o}\right) w_o$	F_b = buoyancy Force (N) ρ = density (kg/m^3) f = fluid o = object w_o = object weight (N) (m•g)

3 Conditions of Buoyancy

1. Objects float if their average density is less than the density of the fluid. $\rho_o < \rho_f$
2. Objects sink if their average density is greater than the density of the fluid. $\rho_o > \rho_f$
3. Objects are in equilibrium if their average density and the fluid's are equal. $\rho_o = \rho_f$

7. Float or Sink Part 1

A solid 0.72 kg cube has a side length of 0.10 m. Will it float in fresh water?

Find the cube's volume, then its density:

$$V_c = l \cdot w \cdot h = (0.10\,m)^3 = 0.0010\,m^3$$

$$\rho_c = \frac{m}{V} = \frac{0.72\,kg}{0.0010\,m^3} = 720\,kg/m^3$$

The cube floats: its density is less than water's.

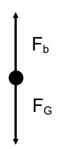
(density$_{H2O}$ = 1000 kg/m^3)

8. Float or Sink Part 2

What percent of the cube's volume is below water?

First determine how much water was displaced.

When it floats, weight equals buoyancy:



$$F_G = F_b$$

$$F_G = mg = \rho_f V_f g = F_b$$

$$m = \rho_f V_f$$

$$\frac{m}{\rho_f} = V_f$$

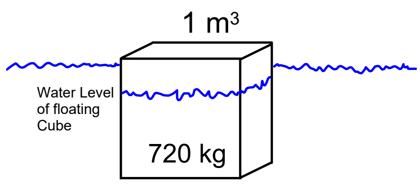
$$\frac{0.72\,kg}{1000\,kg/m^3} = V_f = 0.00072\,m^3$$

Finally, percent: $$\frac{V_{H_2O}}{V_{cube}} \cdot 100\% = \frac{0.00072\,m^3}{0.0010\,m^3} \cdot 100\% = 72\%$$

Float or Sink Conceptual Aid

When average density of object is less than water, consider a cubic meter with some percent water in it.

Ex: density = 720 kg/m^3, would be a cube with 720 kg of water in it, so 28% would be empty, and 72% full.



9. Human Buoyancy in Air Example

Estimate the buoyancy of a 75-kg person in air, assuming that human density averages about that of water.

The density of air is 1.29 kg/m³

Human Buoyancy in Air Answer

Compute the human volume first, then use Archimedes' principle to solve:

Volume: $V_{human} = \frac{m}{\rho_{human}} = \frac{75\,kg}{1000\,kg/m^3} = 0.075\,m^3$

Buoyant force:

$$F_b = (\rho_{air} V_{human})g$$
$$= (1.29\,kg/m^3)(0.075\,m^3) \bullet 9.81\,m/s^2 = 0.95\,N$$

This is about 0.23 pounds, so on a bathroom scale the person actually weighs a little more!

Homework 1.3

Preview 1.4

Problems 1.3 in your Booklet
Due: Next Class