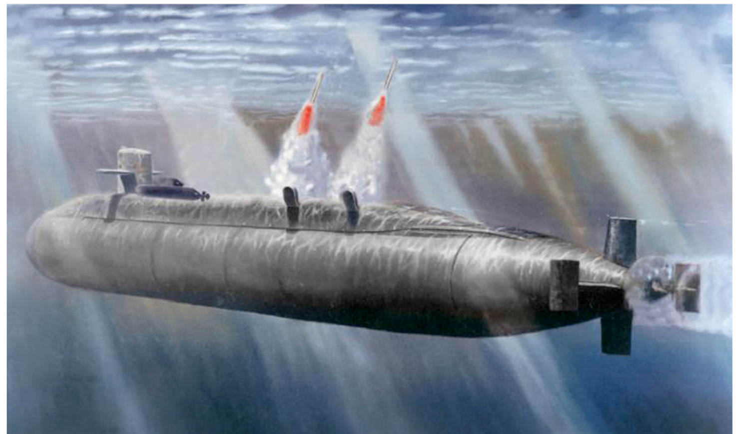
PUTNEY DESIGNS

BUOYANCY …

WHY DO SOME THINGS FLOAT AND OTHERS DON'T

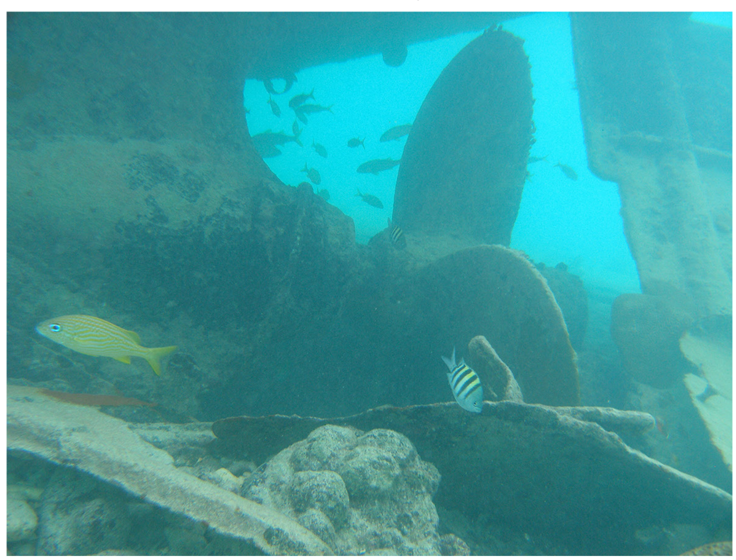
Why do some things FLOAT? Others DON'T?

Cruise Ship



Submarine

Wreck of the Gamma, above & below



Can we PREDICT this?

- Is it WEIGHT?
- Is it SIZE (volume)?
- Is it DENSITY? (Weight / Volume)

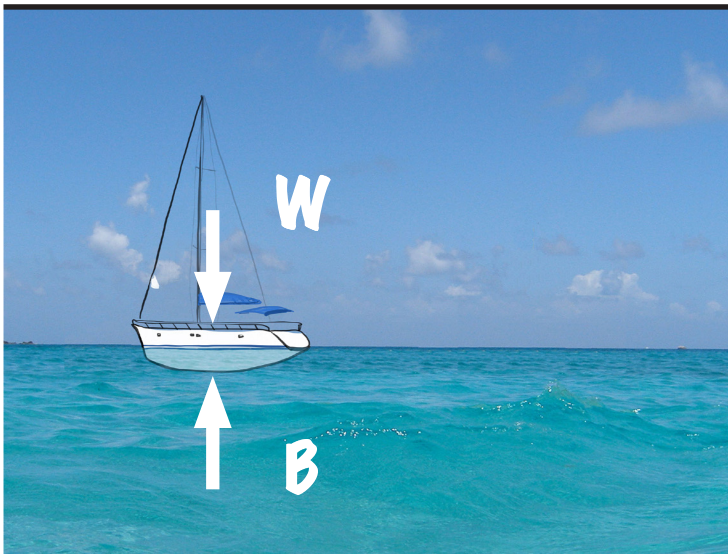
Does MATERIAL matter? (Waterproofing?)

Kayak

- Cruise ship image by Limbovision from Pixabay
- Submarine image from https://www.navy.mil/management/photodb/photos/030814-N-0000X-003.jpg . "The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD endorsement."

BUOYANCY ...

WHY DO SOME THINGS FLOAT AND OTHERS DON'T



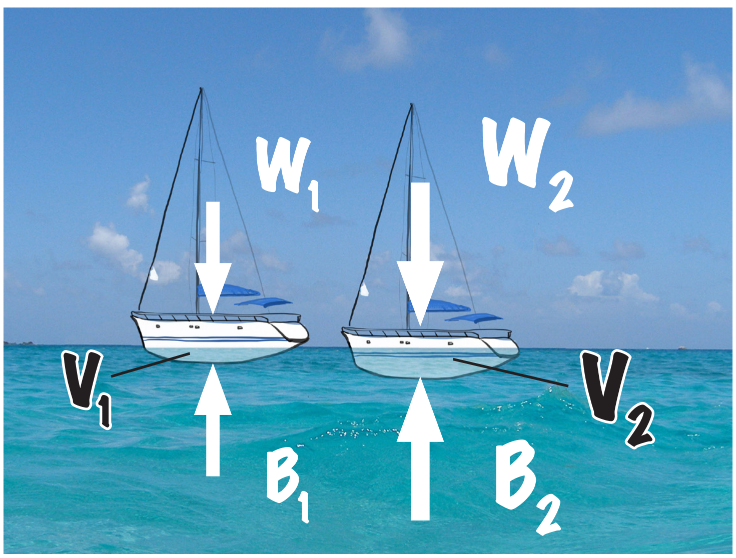
Force balance

Weight is a **force** or **load** that is often modeled as acting on a **point**.

If an object isn't moving, then the forces acting on it must be in balance.

The sailboat at left is resting at anchor. The **weight** of the boat, **W**, is supported by the **buoyant force** of the water, **B**.

W = B

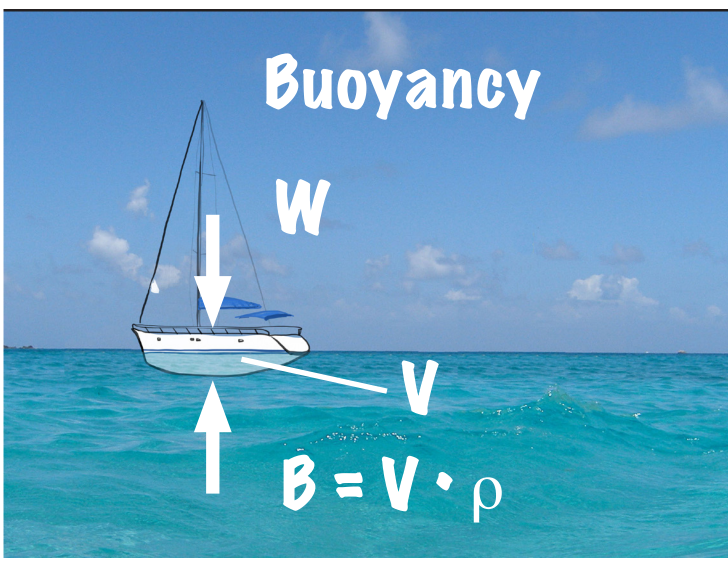


Fluids and Buoyancy

Solids hold their own **shape** and **volume**.
Fluids–*liquids and gases*–have **no fixed shape** and yield easily to pressure.
Liquids–like water–have a **constant volume**.
Gases–like air–will **expand freely** to fill a container, having **no fixed shape**, and **no fixed volume**.

The **weight** of the boat, **W**, causes a **volume** of water to be displaced, **V**, which depends on the **density** of the water, ρ. This is the buoyant force, **B** = ρ • **V**.

We can tell that the boat on the right is heavier than the boat on the left, because the volume of water displaced is larger. $V_2 > V_1$, therefore $W_2 > W_1$.



Sizing a boat

Boats are designed to carry a certain amount of weight, or payload, with a margin of safety.

You can design a cardboard boat using the relationship between density of water, ρ, volume, V, and Buoyant force, B:

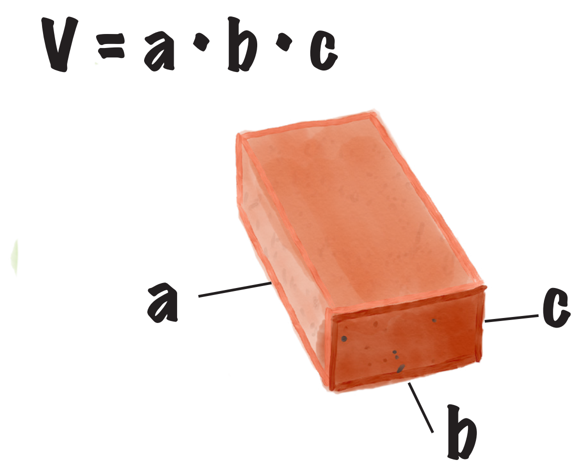
B = W = ρ • V , *or solving for V:*

V = W / ρ

Pick a desired weight, W, and divide by the density of water (in consitent units). This will give you the needed volume. Multiply by desired safety factor.

Note: this handout uses a dot (•) to indicate multiplication.

SOME ADDITIONAL BACKGROUND INFORMATION ABOUT SOLIDS, LIQUIDS AND GASES ...



Volume

Solids hold their own shape and volume.

Volume can be measured or calculated different ways. For **rectangular solids**, like this brick, there's a simple formula–you just need to know the length of each side:

$$V = a \bullet b \bullet c$$

So, a brick 12 inches long by 4 inches wide and 2 inches high would have a volume, V:

V = 12 • 4 • 2 = 96 cubic inches, or 96 in^3

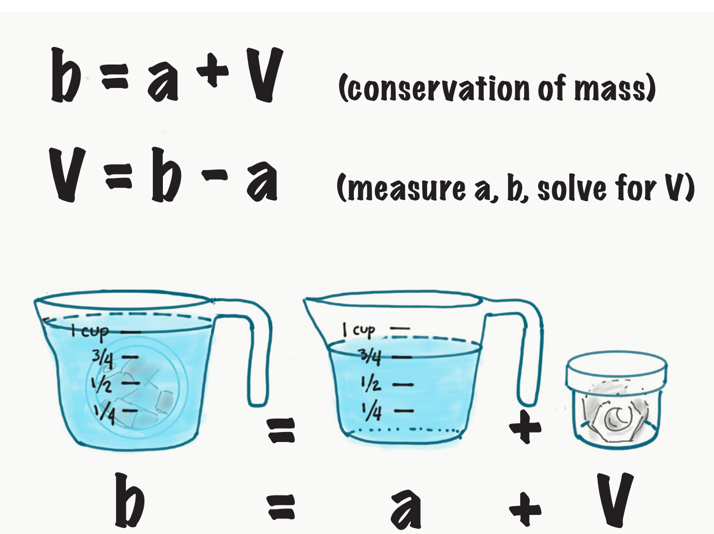
Scientists keep track of the units of measurment–such as inches, feet, or meters. This makes it easier to use conversion factors to translate to a more convenient system of units if needed.

Liquids have a constant volume

If we want to measure the **volume of a liquid**, or measure out a certain amount of a liquid, we can use a calibrated measuring cup.

This makes use of the property of liquids that they take the shape of their container.

This also gives us a clever way to measure the volume of an irregular solid, as we'll see below.



Volume calculation by liquid displacement

In the sketch at left, we want to figure out the volume of the plastic container of hex nuts (far right).

Place the container of hex nuts in the measuring cup, then fill it with water to a known level (1 cup in this example)–figure at far left.

Next, take out the container of hex nuts and measure the level of the water remaining (3/4 cup in this example). We now know the value of a and c, and can solve for b, using conservation of mass (no matter was created or destroyed during this experiment):

V = b - a = 1 cup - 3/4 cup = 1/4 cup

PUTNEY DESIGNS

BOAT SIZING TABLE ...

USE THIS TO FIGURE OUT HOW MUCH WEIGHT YOU CAN FLOAT

Boat Sizing Calculations

Use the following table and equations ("Math Recipes") below to size your boat.

Payload Weight includes the weight of the boat *and* people.

Note: density of water = 0.036 pounds per cubic inch

HINT: *Consider adding extra margin in for waves and splashes* .

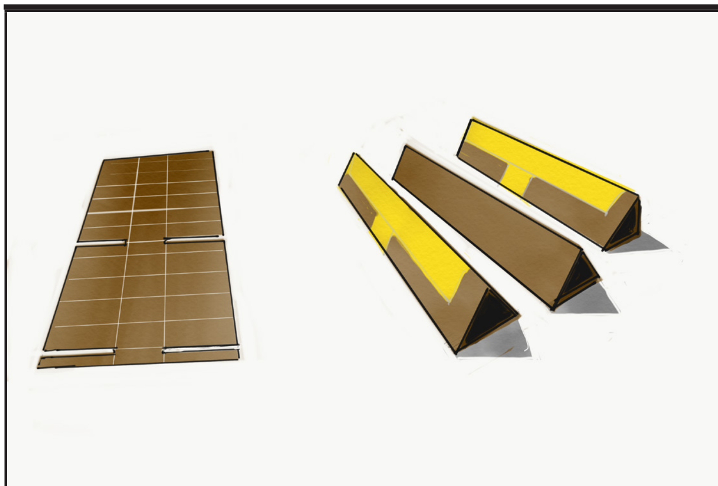
Payload Weight = **Volume** (of water displaced) x **Density** (of water)

Volume (of a rectangular solid) = **Width** x **Length** x **Height**

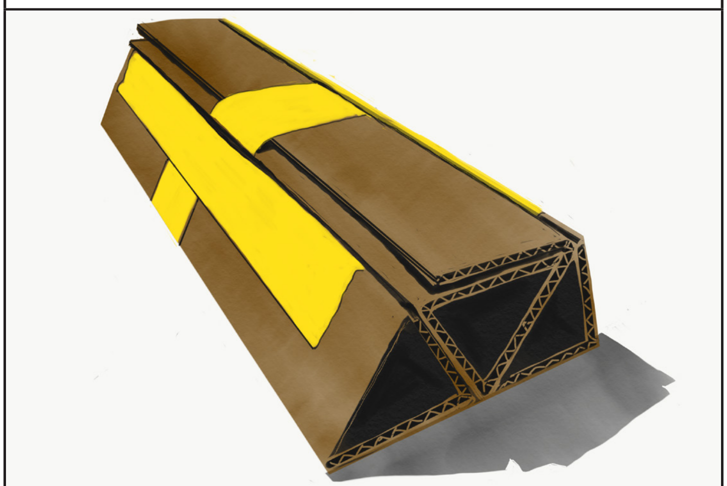
Case #	Width (in)	Length (in)	Height (in)	Volume (cubic inches)	Payload Weight (lbs)	Notes
1	18	48	4	3,456	124	
2	18	48	6	5,184	187	
3	18	48	8	6,912	249	
4	18	60	4	4,320	156	
5	18	60	6	6,480	233	
6	18	60	8	8,640	311	
7	24	48	4	4,608	166	
8	24	48	6	6,912	249	
9	24	48	8	9,216	332	
10	24	60	4	5,760	207	
11	24	60	6	8,640	311	
12	24	60	8	11,520	415	
13	3.75	3.75	1	14	0.5	milk carton
14	3.75	3.75	2	28	1.0	
15	3.75	3.75	3	42	1.5	
16						
17						
18						
19						
20						
21						

CARDBOARD TUBE TRUSSES ...

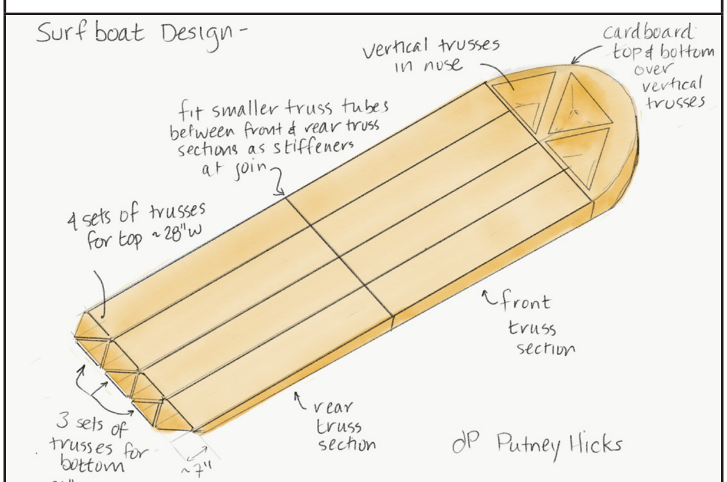
IF YOU NEED STRENGTH + DISPLACEMENT IN YOUR DESIGN



MAKING CARDBOARD TUBE TRUSSES



STACKING TRUSSES TO FORM A STRUCTURE



SURFBOAT SCHEMATIC USING TUBE TRUSSES

BUILDING WITH CARDBOARD

You can make a boat out of just about anything... tape plastic water bottles together for a pontoon boat, or maybe make a raft of styrofoam pool noodles. You can even make a small boat out of the bottom of a cardboard milk carton (dimensions given in the table on page 4).

But, the volume calculations are simpler for rectangular shapes, and you can do a lot with cardboard–make it any size and shape you want!

Corrugated cardboard is the strongest... if you look at a cut edge, you can see it has a mini-triangular truss structure built into it. Trusses–triangles–form one of the most common structural building elements.

If you'd like to **build a strong base** for your cardboard boat, may I suggest using **card-board tube trusses**?

You can use trigonometry to figure out the ideal width of your triangle sides, but it's not necessary. **Just make the sides a bit longer than the desired height**. Your box dimensions will probably be a bigger constraint–pick dimensions so you get flat sides without folds.

You'll need to **score the cardboard** to help it **bend where you want it to**. You don't want extra bends along the length of your sides... because it will act like another side. When you load it, it will bend like a **hinge**, giving you a **mechanism** not a **structure**. Folds perpendicular to the load direction aren't a problem.

PUTNEY
DESIGNS

CARDBOARD BOAT RACE PICTURES ...

SURFBOAT + TWO CONVENTIONAL BOATS RACED IN A POOL!

START LINE ... BLUE, GREEN, & RED TEAMS

GREEN TEAM... BEFORE SINKING IN RACE 2

... AND WE'RE OFF!

RED TEAM... BEFORE SINKING IN RACE 3

THE SURFBOAT PULLS AHEAD EASILY

THE UNSINKABLE SURFBOAT - VICTORY LAP!