Floating with Surface Tension

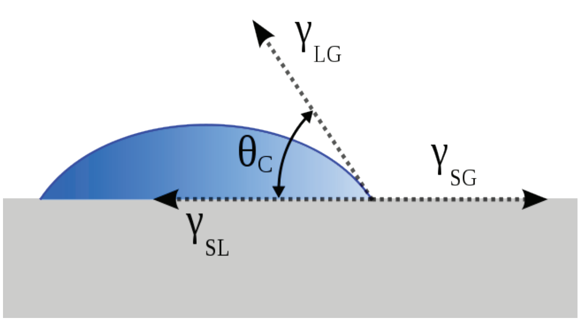
When a large object like a log or a boat floats on water it is because the object is less dense than the water it is displacing. Small objects like dust, paper clips or insects like water striders can float on water even though they are much more dense than the water. How do they do it? They use surface tension. Surface tension is a force per unit length caused by an attractive force between molecules that holds them together. It is the property of liquids that pulls them into a spherical shape to minimize the surface area, but it can also exhert a force on a solid that can support the weight of a heavy object and keep it from sinking. In this experiment, we will try to make heavy objects float and see first-hand why the size of the object we try to float makes a difference.

What you will need to get started

- 3 or 4 acrylic spheres and cubes of different sizes (3/8”, 1/4” and 1/8” recommended)
- Clear plastic cups
- Water
- Plastic spoons for placing spheres on top of the water
- Paper towels and a small dust pin and broom

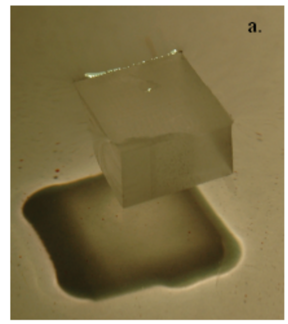
Why use acrylic?

- Density of acrylic is 1.18g/cm^3 – 18% more dense than water so it should sink.
- Liquids and solids interact through surface tension, γ, and contact angle, θ
- If water likes a surface, the contact angle is small, $\theta < 90^o$, and the surface is hydrophilic
- If water dislikes a surface, the contact angle is large, $\theta > 90^o$, and the surface is hydrophobic
- Acrylic is hydrophobic – it doesn’t like to be wet by water – it wants to stay dry
- The larger the surface tension the larger the force



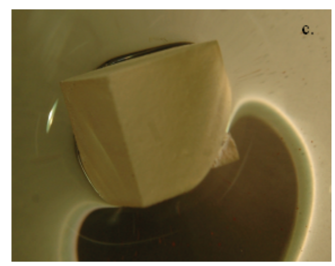
Let's experiment!

1. First, place the largest sphere carefully on the surface of the water.
   - Does it sink or float?



2. Now place the middle sized sphere on the surface of the water
   - Does it sink or float? Your results might change if you are really careful placing the sphere

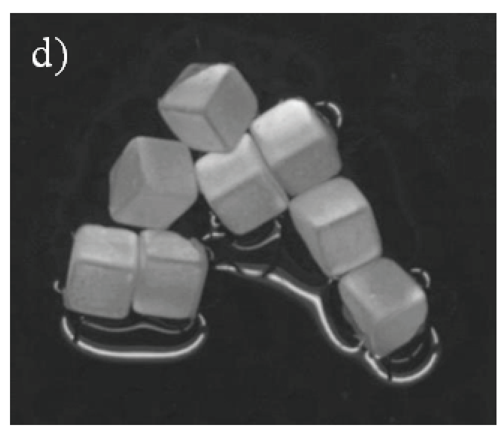
3. Now predict whether the smallest sphere will sink or float.
   - Where you right? Is this cube sensitive to how you place it on the surface? Can you drop it?

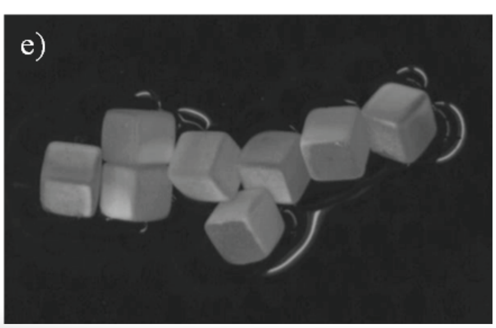


4. Look closely at the surface of the water where the sphere is floating. Is it flat? Is it distorted or bent?

5. Now place a second, third or fourth sphere on the surface of the water.
   - What happens? Do the spheres stay where you placed them? Do they move?

6. Repeat the exeperiments with the cubes.
   - What happens? Compare your results to the spheres. What's the same? What's different?





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How does it work?

For a dense object to float on water, the force exerted on the object from surface tension must be bigger than the force of gravity pulling it down. Here the force of gravity on the sphere is given by the volume of the sphere times its density times the acceleration of gravity.

$$F_{gravity} = 4/3\pi R^3(\rho_{acrylic} - \rho_{water})g$$

The force from surface tension is given wetted perimeter of the sphere times the surface tension.

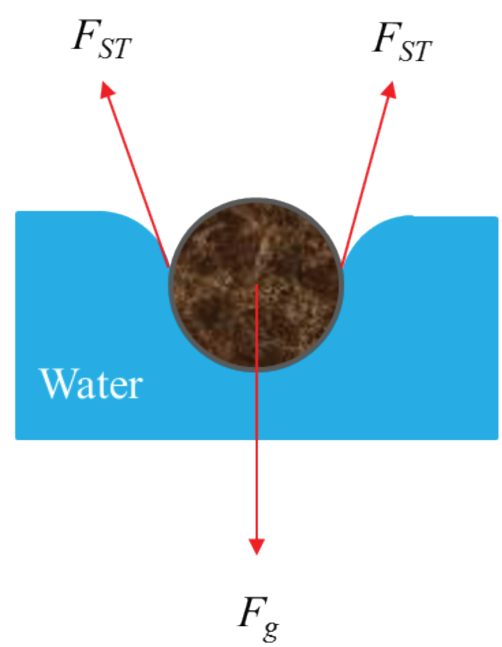
$$F_{surface\ tension} = 2\pi R\gamma$$

If $F_{surface\ tension} > F_{gravity}$ the sphere will float. If we rearrange the equations we see that this inequality holds when the square of the radius of the sphere is less than

$$R^2 < 3/2\ \gamma / (\rho_{acrylic} - \rho_{water})\ g$$

So as the sphere gets smaller surface tension eventually wins. For an example from the real world, surface tension can support the weight of a insect like a water strider. With its six legs on the water, surface tension can support an insect mass of up to 250mg. That's much more than the mass of the water strider meaning the insect can push on the surface of the water and not sink in. This lets it "walk" across the surface of the water and even jump off the water like it was on a trampoline.

Force Balance on a Floating Sphere



Water Strider

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