Title: Physics in Nature Presentation: Surface Tension in Nature

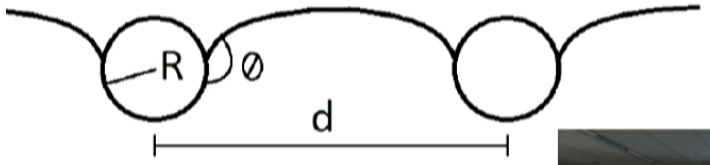
Date: Aug 19, 2011 03:30 PM

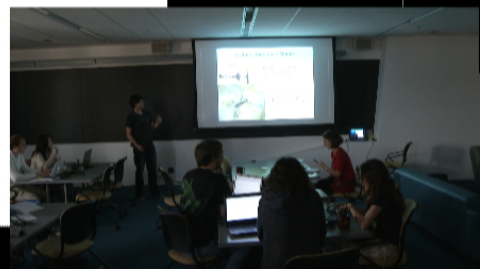
URL: http://pirsa.org/11080108

Abstract:

Surface Tension in Nature

Jonathan Blackman
PSI Presentations
August 19 2011





What is surface tension?

- Archimedes' principle fails to explain why some small objects more dense than water can float.

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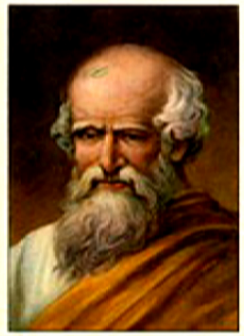
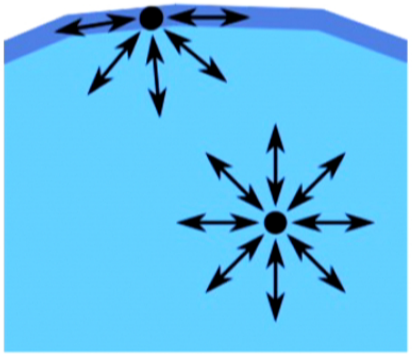


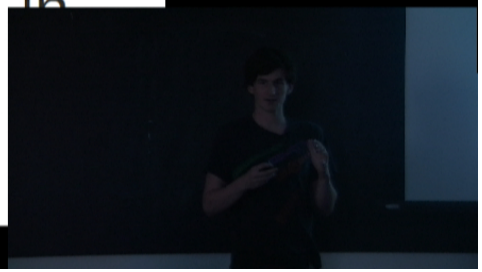
(Buoyant force) = (Weight of displaced flu
< (Weight of object)

What is surface tension?

- Intermolecular attractive forces, such as Hydrogen bonding in the case of water, cause the molecules on the surface to be attracted into the fluid.



- This causes the fluid to stay together, and retain a smooth boundary.
- Surface tension can also be interpreted in terms of minimizing surface energy.



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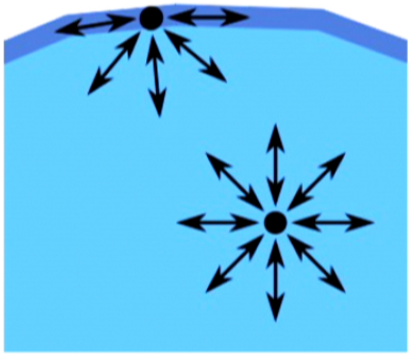

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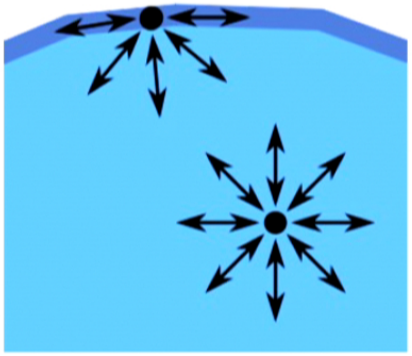

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Surface tensions of common liquids

- Surface tension has dimensions
  (Force)/(Length) = (Energy)/(Length^2)

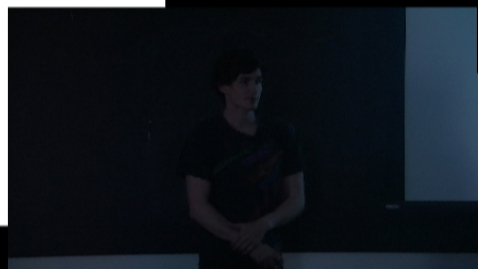
Water
~0.07 N/m

Mercury
~0.5 N/m

Water Striders

- More dense than water
- Float due to surface tension acting on long legs

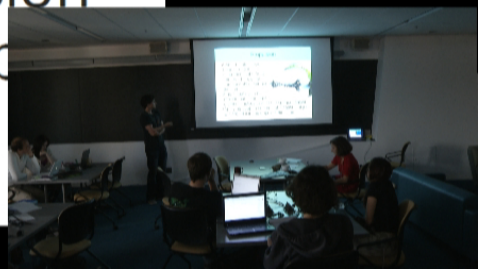
- Weight ~ ρg(Length)^3
- Surface tension forces ~ σ(Length)
- Need L smaller than ~ √(σ/ρg)



Propulsion

- Some beetle larvae bend, creating a difference in the front and rear horizontal components of surface tension.

- Small boats with no moving parts can emit electrical pulses to alter the surface tension
- Applying soap to one end of a floating ob will propel it in the opposite direction



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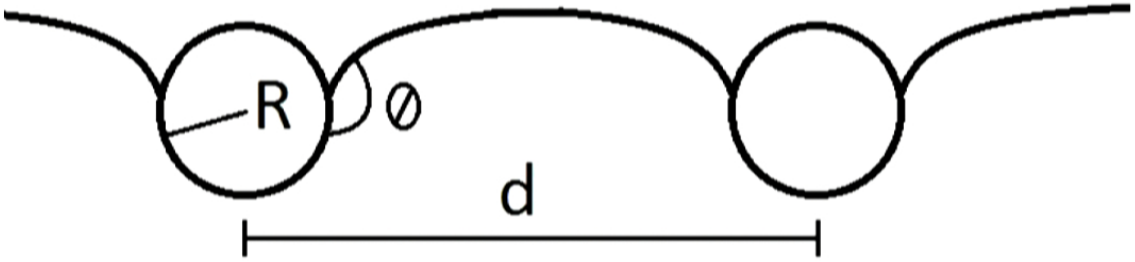
Capillary Attraction

"Cheerios Effect" - Similar objects floating on a fluid tend to be attracted to each other.

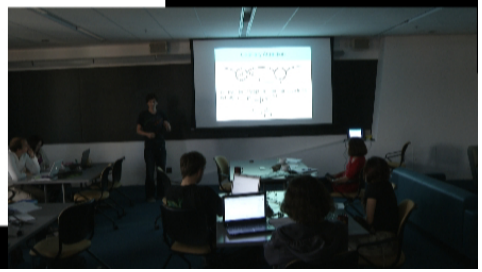
Capillary Attraction



For two identical spheres, the attractive force is roughly

$$F_c = \beta e^{-d/L_c}$$

$$L_c = \sqrt{\frac{\sigma}{\rho_f g}}$$



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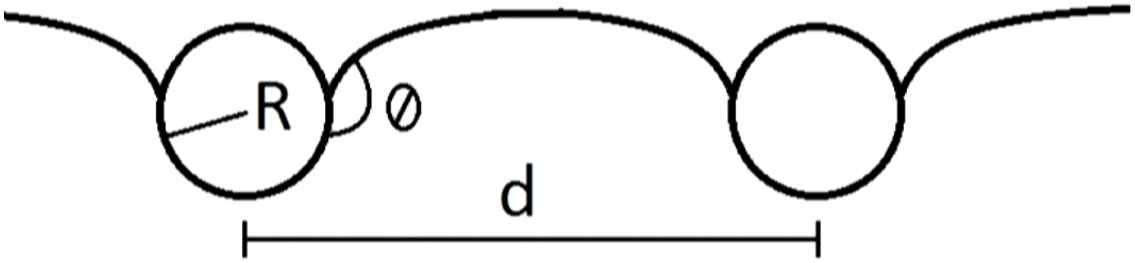

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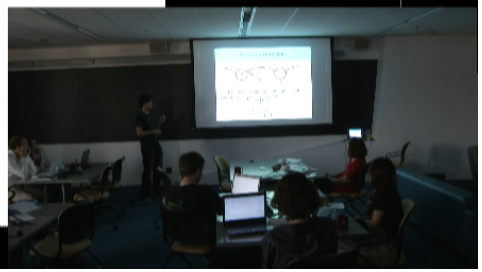
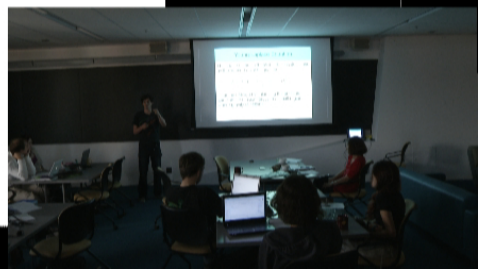


Young-Laplace Equation

The shape of the fluid-gas interface is described by the Young-Laplace equation

$$\Delta p = 2\sigma H = \sigma\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = -\sigma \nabla \cdot \hat{n}$$

It can be derived by balancing the pressure and surface tension forces in a small region, where gravity is negligible.



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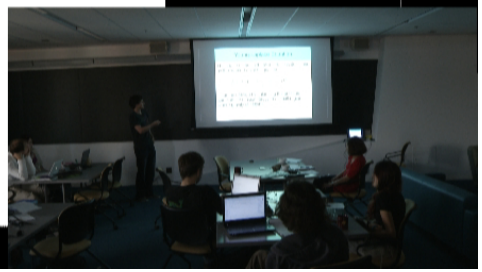

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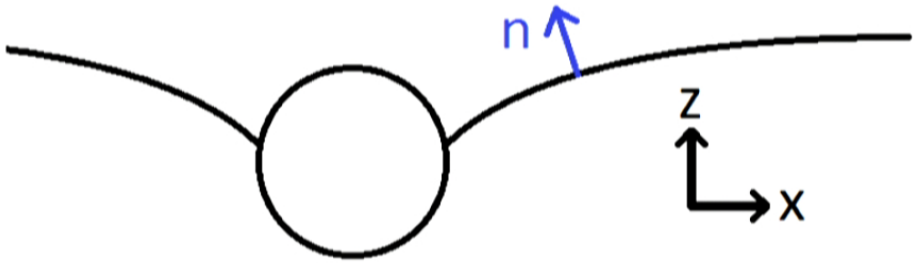
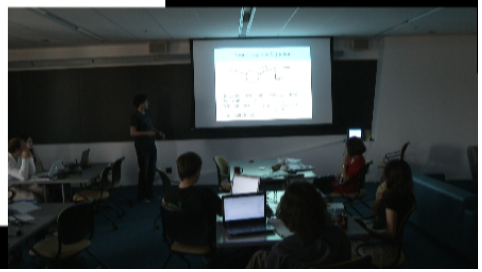


In a simple two dimensional system we can write z = f(x).
We then have

$$\nabla \cdot \hat{n} = \frac{\ddot{f}}{\left(1+\left(\dot{f}\right)^2\right)^{3/2}} \approx \ddot{f}$$

for small slopes.



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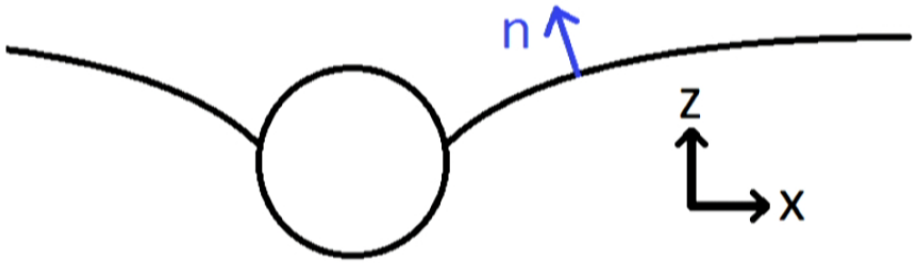

The pressure of the fluid under the force of gravity is $p_0 + \rho g z$, so the equation is

$$\rho g f = \sigma \ddot{f}$$

so

$$z \approx z_0 e^{-x/L_c}$$

Summary

- Surface tension is caused by attractive intermolecular forces, and the minimization of the surface energy.
- It allows dense objects to float, provided that they are sufficiently small.
- It also gives rise to a force between floating objects.
- Surface tension effects typically decay exponentially with distance