

Misconception Regarding Direction of Macroscopic Surface Tension

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Abstract

This *Misconception* is initially proposed by 吳俊緯, classmate of Chiayi Senior High School's 12th science class.

Argument

At the surface of a water surface, the cohesion forces on a water molecule isn't well balanced by the surrounding water molecules like those not on the surface. Instead, there is a *net force* pulling the molecule *backwards*, minimizing the surface area (and hence the surface energy) of the system. From this point of view, the direction of surface tension γ seem to be normal to the water surface, because it is making the surface smaller.

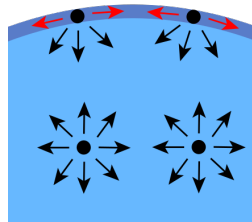


Figure 1: Forces on water molecules [2]

However, we can also consider the classical setup: a U-tube apparatus made to measure the surface tension. At the edge of the U-tube or the rod (where a force F is exerted on), the surface tension pulls in the tangential direction. It can also be seen on the particles not on the boundary that γ is balanced in opposite directions, hence creating a *tension*

in the *tangential* direction. When discussing the contact angle, meniscus effects and other phenomena, one often takes γ to be tangential to the surface. Which viewpoint is correct?

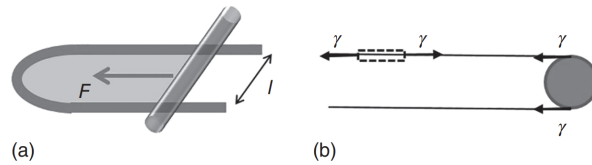


Figure 2: U-tube setup [3]

Misconception

The main conception here is that if the surface tension acts inwards, it will also reduce the *volume* of the liquid drop (for instance), which is definitely not the case. By prompting ChatGPT with

What is the direction of surface tension between two surfaces? Is it along their tangent or the normal? Why?

I obtain the following response.

...Imagine a small imaginary line or curve drawn on the liquid surface. At each point along this line or curve, there will be cohesive forces between the liquid molecules. These cohesive forces act tangentially along the surface of the liquid, trying to pull the liquid molecules together. This creates a net force along the tangent direction, resulting in a tendency to minimize the surface area.

If the surface tension force acted in the normal direction (perpendicular to the surface), it would cause the liquid to contract inwards, leading to a reduction in volume and not just surface area. However, we observe that liquids tend to form a shape with the least surface area while maintaining their volume. This behavior is only possible if the surface tension acts tangentially along the surface.

[1]

That, however, does not completely solve the problem. For a water-air surface, we only know that it acts in the tangential direction, but is it towards the water or the air?

Solution

References

- [1] ChatGPT-3.5. Personal communication. July 30, 2023.
- [2] Booyabazooka (username). [Diagram of the cohesive forces on molecules of a liquid](#). 2008.
- [3] Wiley-vch. Introduction to capillarity and wetting phenomena. 2019.