Student solves a 100-year-old physics enigma

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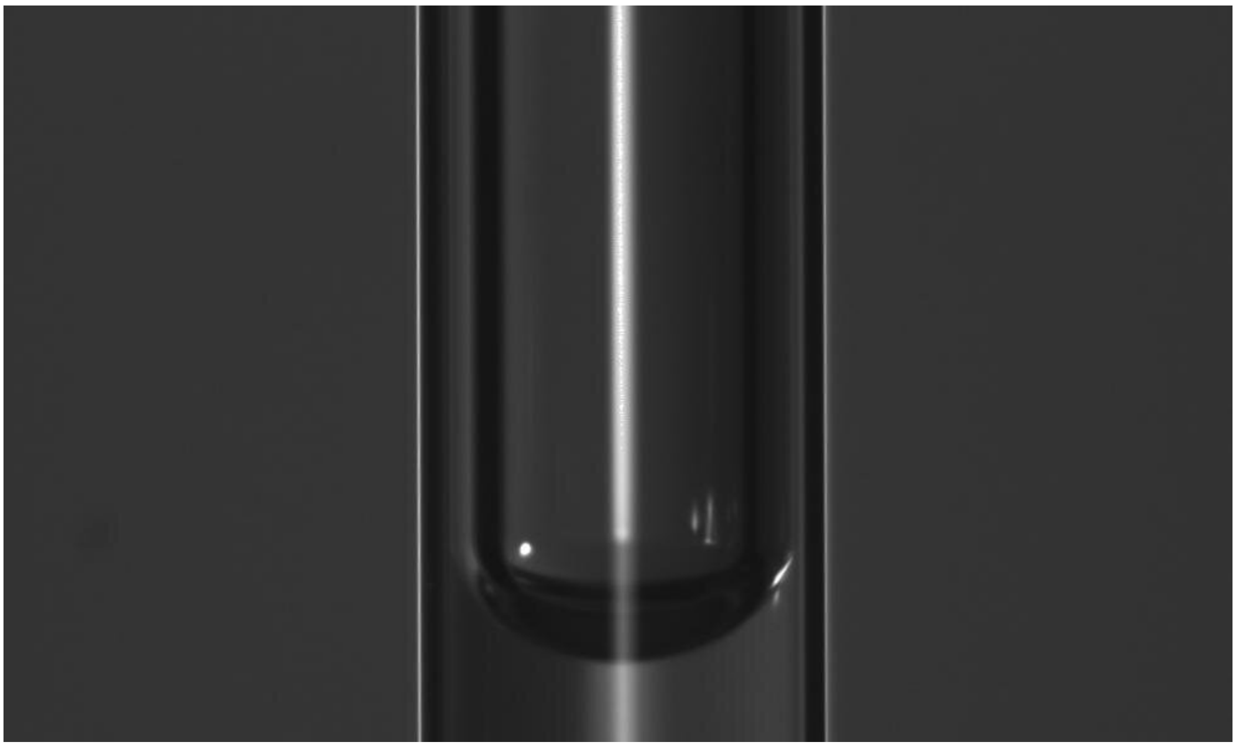

The bubble not rising upward Credit: EPFL

An EPFL Bachelor's student has solved a mystery that has puzzled scientists for 100 years. He discovered why gas bubbles in narrow vertical tubes seem to remain stuck instead of rising upward. According to his research and observations, an ultra-thin film of liquid forms around the bubble, preventing it from rising freely. And he found that, in fact, the bubbles are not stuck at all—they are just moving very, very slowly.

Air bubbles in a glass of water float freely up to the surface, and the mechanisms behind this are easily explained by the basic laws of science. However, the same laws of science cannot explain why air bubbles in a tube a few millimeters thick don't rise the same way.

Physicists first observed this phenomenon nearly a century ago, but couldn't come up with an explanation—in theory, the bubbles shouldn't encounter any resistance unless the fluid is in motion; thus a stuck bubble should encounter no resistance.

Back in the 1960s, a scientist named Bretherton developed a formula based on the bubbles' shape to explain this phenomenon. Other researchers have since postulated that the bubble doesn't rise due to a thin film of liquid that forms between the bubbles and the tube wall. But these theories cannot fully explain why the bubbles don't rise upward.

While a Bachelor's student at the Engineering Mechanics of Soft Interfaces laboratory (EMSI) within EPFL's School of Engineering, Wassim Dhaouadi was able to not only view the thin film of liquid, but also measure it and describe its properties—something that had never been done before. His findings showed that the bubbles weren't stuck, as scientists previously thought, but actually moving upwards extremely slowly. Dhaouadi's research, which was published recently in *Physical Review Fluids*, marked the first time that experimental evidence was provided to test earlier theories.

Dhaouadi and EMSI lab head, John Kolinski, used an optical interference method to measure the film, which they found to be only a few dozen nanometers (1×10^{-9} meters) thick. The method involved directing light onto an air bubble inside a narrow tube and analyzing the reflected light intensity. Using the interference of the light reflected from the tube's inner wall and from the bubble's surface, they precisely measured the film's thickness.

Dhaouadi also discovered that the film changes shape if heat is applied to the bubble and returns to its original shape once the heat is removed. "This discovery disproves the most recent theories that the film would drain to zero thickness," says John Kolinski.

These measurements also show that the bubbles are actually moving, albeit too slowly to be seen by the human eye. "Because the film between the bubble and the tube is so thin, it creates a strong resistance to flow, drastically slowing the bubbles' rise," according to Kolinski.

These findings relate to fundamental research but could be used to study fluid mechanics on a nanometric scale, especially for biological systems.

Dhaouadi joined the lab as a summer research assistant during his Bachelor. He made rapid progress, and continued the work of his own volition. "He essentially participated out of his interest in the research, and wound up publishing a paper from his work that brings to rest a centuries-old puzzle," says Kolinski.

"I was happy to carry a research project early in my curriculum. It is a new way of thinking and learning and was quite different from a Homework set where you know there is a solution, although it may be hard to find. At first, We did not know if there would even be a solution to this problem.," says Dhaouadi, who is now completing a Master's degree at ETH Zurich. Kolinski adds: "Wassim made an exceptional discovery at our lab. We were happy to have him working with us."

More information: Dhaouadi, Wassim and Kolinski, John M., Bretherton's Buoyant Bubble, *Physical Review Fluids*, 2019, DOI: 10.1103/PhysRevFluids.4.123601

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