Group project 1 — Ooze tube

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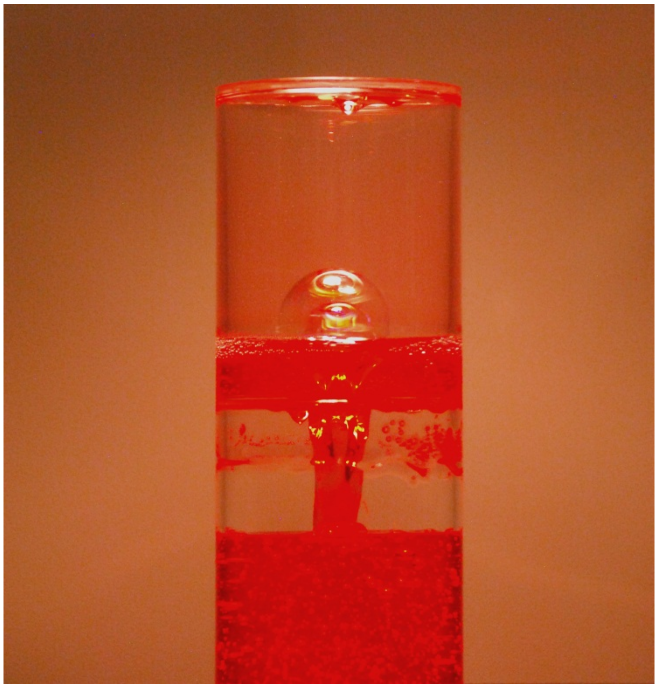

Ooze tube is a normal desk toy with a lot of interesting viscous flow phenomena inside. The intent of the image is to show the viscous flow of the liquid inside and the bubble generation/moving. The flow of liquid may contain information about instability and the bubble generation/moving reflect the surface tension and pressure in the tube.

It was in a dark room while a LED desk light was the only light source. The background was a huge rough white board which could generate diffuse reflection. The light was shined from the top of the ooze tube. The camera was in front of the tube and perpendicular to the light direction. Tripod was used to avoid motion blur in such dark environment. The apparatus and positions are in figure 1. When the tube was flipped upside down, the viscous liquid inside flew through the hole on the middle acrylic disc. The liquid flew in laminar regime and bubbles formed in the opposite direction of the flow and rise to the liquid /air interface. The tube has a diameter of 8cm

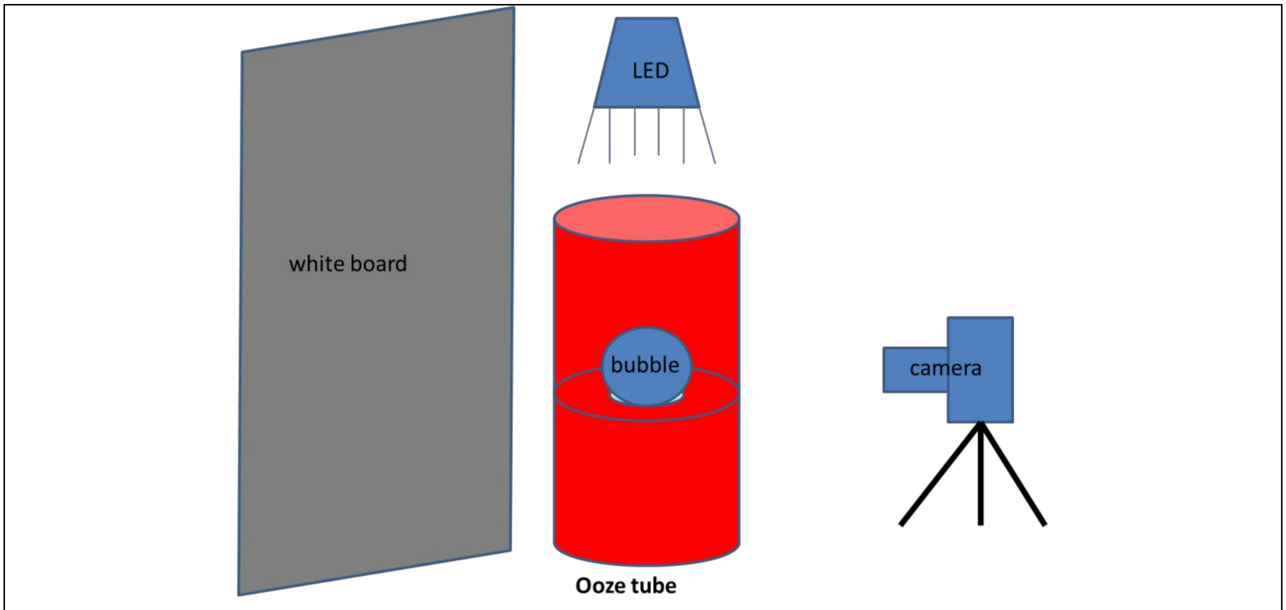

Fig. 1 schematic of the apparatus and positions

and the height is 21cm. By measuring the weight of the tube with the liquid inside, we roughly calculated the density of the liquid to be $1.12 g/cm^3$. It seemed that the bubble moved with a constant speed. So the force acting on the bubble was in balance. This is a bubble and the gravitational force could be ignored. So the dragging force and the buoyance force were in balance. The dragging force is $D=6\pi\mu rU$[1] while the buoyance force is $B=\rho g 4/3\pi r^3$, where r is the radius of the bubble, ρ is the density of the liquid, g is the gravitational acceleration, and U is the speed of the bubble. If we know the speed of the bubble, we could estimate the viscosity of the liquid.

Although we don't know the properties of the liquid, it was still quite clear that the flow through the hole was laminar flow. The high viscosity (which was implied by the slow motion of the bubble) resulted in a stable flow without any instability development. The most common instability that could be seen in a jet flow is the Kelvin-Holmholz instability which is the result of the high relative speed on the interface of two different liquid[2]. Due to the high viscosity and the slow speed of the liquid flow, the K-H instability couldn't develop. So the liquid flowing downward had a very neat and clear shape. Usually there should be deformation when the bubble moves against gravity[3]. However, the slow departure from the hole reduced the momentum change and the high viscosity made the bubble perfect sphere all the way to the top of the liquid.

The viscous liquid in the ooze tube itself is red. So it can work as dye itself when the flow is in the air. When we tried to get images of the bubbles, the bubbles which have different reflectivity made them visible in the liquid. The LED desk light worked very well to show the shape of the flow and the bubbles in a dark room. No flash was used. The white board worked well as the background to provide diffuse reflection.

The field of view is about 1ft by 1ft. The distance from the object to the lens is about 2ft. The lens focal length is 75mm. The maximum aperture is 4.9. This is a Nikon D80 digital camera. This resolution of the image is 2033x2124 pixels. The exposure time is 1/60 second and the f stop is f/6.3. The ISO is 640. When I edited in Photoshop, I adjusted the contrast and the exposure level so that the bubbles are clear.

The image presents the bubbles and the nice laminar flow in the ooze tube. I like the two clear bubbles. Due to the lack of liquid properties the fluid physics were not clearly explained. Next time I'd rather use glycerin or other viscous liquid to present laminar flow.

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[1] P.K.Kundu, I.M.Cohen, Fluid Mechanics 4th edition, Elsevier, London, 2008
[2] V.P.Carey, Liquid-Vapor Phase-Change Phenomena: An Introduction to the Thermophysics of Vaporization and Condensation Processes in Heat Transfer Equipment, Washington, Second Edition, 2007.
[3] L.Chen, S.V. Garimella, *et al.*, "The Development of a Bubble Rising in a Viscous Liquid", Journal of Fluid Mechanics, vol. 387, pp. 61-96