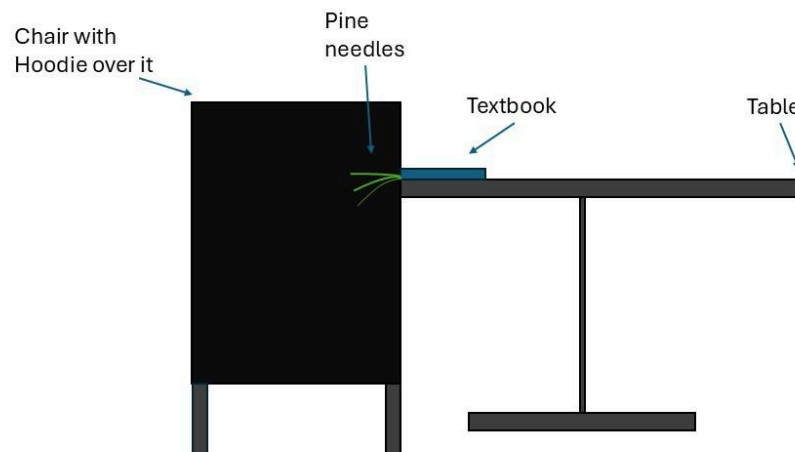


The image shows two small water droplets suspended on the ends of pine needles set against a dark background. The goal of this shot was to be able to visualize the interception of rain drops by conifer needles before they reach the ground. Originally I planned to do this by taking pictures of actual rain drops on a pine tree during a thunderstorm, however this proved ineffective as the motion of the pine needles due to wind combined with the much messier background of the tree itself made it impossible to get a clean visual where the desired phenomena was clearly visible.

The apparatus used to capture the flow was rather simple due to the somewhat DIY nature of the assignment. The pine needles were held in place by pinning them to a table with an old stats textbook. The background was created by using a black hoodie draped over a chair. The water for the droplets was applied by dripping water off of my fingers onto the base of the pine needles.



The shot was primarily backlit using natural lighting from the sun on a very cloudy day resulting in the diffuse light framing the needles and droplets. There are two primary forces that are acting on the water droplets in order to keep them in equilibrium suspended from the pine needles. Gravity is acting downwards on the droplet and the surface tension of the water is acting inward on the droplet keeping it intact, and pulling it upwards towards the needle. The balance between these forces can be described using the Bond number (Hager 2012).

$$Bo = (g\rho)L^2/\sigma$$

Bo is the Bond number, g is gravity, ρ is the liquid density, L is the characteristic length, and σ is the surface tension of the fluid. The surface tension and density of the water both depend on the water's temperature which will be estimated at 80°F or 26.7°C as this was the outdoor temperature at the time and the water was roughly at temperature equilibrium. This puts the surface tension at 0.72 N/m and the density at 996.61 kg/m³. The length of the radius of the water droplet can be estimated at roughly 5 mm or 0.005 m. Using standard Earth gravity of 9.81m/s² the Bond number can be estimated as:

$$Bo = \frac{(9.81m/s^2 * 996.61 kg/m^3)(0.005 m)^2}{(0.72 N/m)}$$

Giving us a Bond number of 0.34. Since this Bond number is below 1 it indicates that the surface tension is the dominant force acting upon the water droplets, as can be seen from the fact that they stayed suspended from the pine needles. If the droplets were large enough for the bond number to become larger than 1 then gravity would take over as the dominant force, and the droplets would fall from the needles. This value is useful for understanding rain interception on pine needles as it dictates the maximum amount of water that one needle could capture due to their low surface area preventing any water from staying on top of the needle as could occur for non-coniferous plants.

The flow visualization technique used was an index of refraction technique. The droplets form a water-air interface as they form, and the differing refraction indexes of the two fluids allow for the boundary to be easily seen with appropriate lighting. The image was lit using natural light on a cloudy day. The apparatus was set up to have the sun, which was fully hidden by clouds, behind the background. This created a soft, diffuse backlight which helped to emphasize the boundary layer between the droplets and the surrounding air, as well as to rim light the pine needles helping them pop against the dark background.

FOV	16 cm x 12 cm
Distance	40 cm
Lens Specs	13 mm Focal Length
Camera Type	Apple iPhone 14 Pro Ultra Wide Camera
Image Size	4032 x 3024 pixels
Aperture	2.2
Shutter Speed	1/89 s
ISO	320

The image processing was fairly light with the only adjustments being to the color scales. The tone equalizer was used to even out and darken the background as it was originally more of a gray scale than the more solid black in the final image. The rgb curve tool was then used to

make the pine needles brighter to balance the image out and make them more visible against the background.



Img 1: Original photo pre-editing

As talked about above the image shows two water droplets each suspended from a separate pine needle. I personally really like the overall look of the image and feel that the simplicity allows the beauty of the physics to shine through. The physics are really visible and clearly the main focus of the shot and the water droplets are clear enough to see the full effects of the surface tension. Overall I feel that I did fulfill my intent with the image and that the effects and vibe of the image match what I had envisioned. I do think that the image could be improved using a proper macro lens as it could be zoomed in even further and the small details of the shot would come out crisper with dedicated instruments. I also think the idea could be developed further through a series of images where another droplet runs down the length of the needle eventually merging with the droplet suspended at the end causing the merged droplet to fall from the needle. I think this would be a good visual of the Bond number changing and gravity becoming the dominant force.

Citations:

Hager, W. H. (2012). Wilfrid Noel Bond and the Bond number. *Journal of Hydraulic Research*, 50(1), 3–9. <https://doi.org/10.1080/00221686.2011.649839>

Peruzzo, P., Defina, A., Nepf, H. M., & Stocker, R. (2013). Capillary interception of floating particles by surface-piercing vegetation. *Physical Review Letters*, 111(16). <https://doi.org/10.1103/physrevlett.111.164501>