Phenomenon# 7 مشاہدہ #۷

Pendant Drop

اٹکا ہوا قطرہ

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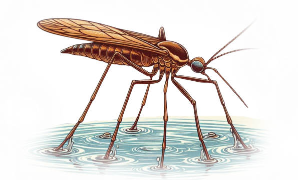
کیا آپ نے کبھی پانی پر چلنے کا خواب دیکھا ہے؟ ہاں ! پانی پر چلنا ممکن ہے، لیکن آپ کے لیے نہیں، ایک کیڑے کے لیے جسے "واٹر اسٹرائیڈر" کہا جاتا ہے۔ کیا یہ ایک سپر پاور ہے یا یہ صرف فزکس کا کمال ہے؟



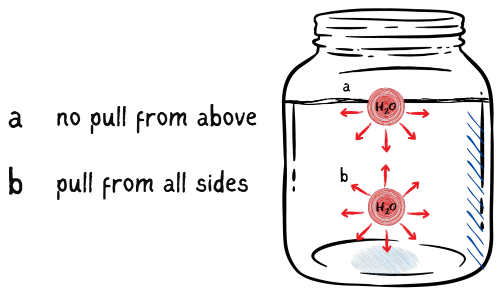
ہم سب نے اپنے بچپن میں بارش میں ضرور کھیلا ہوگا یا صابن کے بلبلے بنائے ہوں گے، اگر ہم آپ کو یہ بتائیں کہ ہم ان مظاہر میں فزکس تلاش کر سکتے ہیں تو آپ کو کیسا محسوس ہوگا؟ یہ سب سطحی کشش (surface tension) کے مظاہر ہیں۔ سطحی کشش ایک خاصیت ہے جو کسی مائع کو کم سے کم سطحی رقبہ حاصل کرنے کی طرف مائل کرتی ہے۔

سطحی کشش کی وجہ سے شبنم کے قطرے گنید کی طرح گول بن جاتے ہیں۔ نلکوں سے ٹپ ٹپ کرتا پانی قطروں کی صورت اختیار کر لیتا ہے۔ دراصل ایک گول کُرہ کسی بھی حجم (volume) کے لیے کم سے کم سطحی رقبہ فراہم کرتا ہے۔ سطحی کشش کی بہتر سمجھ کے لئے ہم ایک چھوٹا سا تجربہ کر سکتے ہیں۔ ایک سوئی یا دھاتی کلپ لے کر اسے پانی پر دھیرے سے رکھیں۔ دھاتی کلپ سطح پر بیٹھ جائے گی، حالانکہ یہ پانی سے زیادہ کثافت (density) رکھنے والے مواد سے بنی ہوتی ہے۔ اگر آپ اسے چھوئیں تو وہ پانی میں ڈوب جائے گی۔ چلیں مشاہدہ لیب میں ایک اور تجربہ کر کے دیکھتے ہیں۔

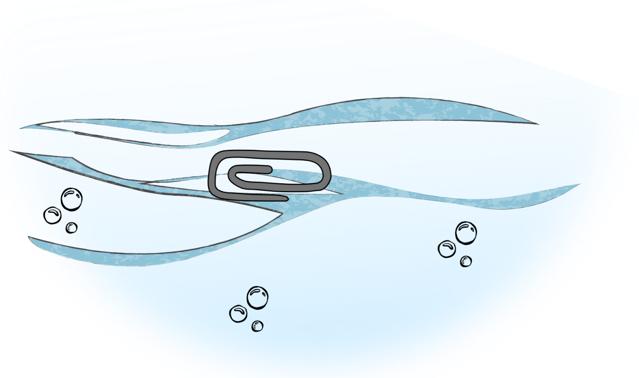
Whether playing in the rain or making soap bubbles as children, we encounter science in all these simple joys.

Soap bubbles, dewdrops, and water dripping from a tap are all examples of surface tension. Surface tension is a property that minimizes the surface area of a liquid. Increasing the surface area requires additional energy. Consider a quantity of water. When suspended in the air, like a raindrop, perched on a spider web, or as a dewdrop, the water naturally forms a shape with the minimum surface area—a sphere. This is why water forms droplets. In the absence of gravity, such as in a spaceship, these droplets would be perfectly spherical.

Surface tension is caused by molecular forces. Consider water in a drinking glass. Molecules beneath the surface experience forces from other molecules from all sides, top, bottom, left, and right. All these forces cancel out.



However, a molecule on the surface does not experience any forces from above, so the molecules below the surface pull surface molecules downward. This means the surface is pulled inward and acts like an elastic sheet. This sheet is hard to break. Even if a heavy object is gently placed on the surface, the sheet will not break, allowing the object to float on the surface. Steel is denser than water, so it should sink; but when a steel razor blade is gently perched on the surface of water, it can remain afloat. This is surface tension.



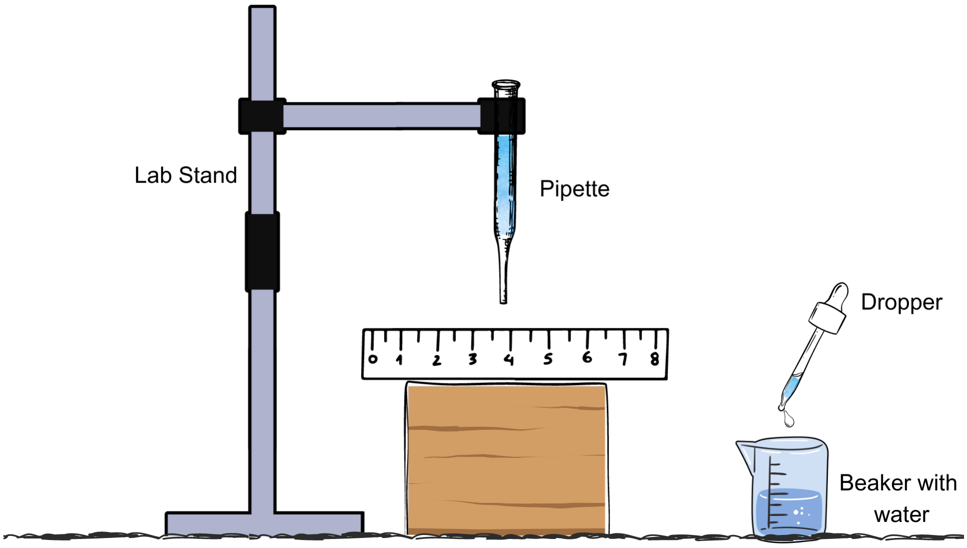


Figure 1: An overview of the setup to capture an image of a water drop

Let's make sure we have everything we need shown in Fig.1

1. Lab stand
2. Thin glass tube (pipette)
3. Container with water
4. Ruler
5. A support for lifting the scale
6. Dropper

When a tube is filled with a liquid, which is then allowed to gradually drain, a small drop may form at the edge. You must have seen such a drop hung from the tip of a water faucet. Due to surface tension, this water drop tends to take a spherical shape. However, gravity elongates the hanging drop and stretches it into a pear shape. This shape is also called a pendant. From the shape of this pear, we will estimate the surface tension.

Dip a pipette or tube into a bowl of water, drawing in some water. Then while the tap on the pipe is closed, hold it on a stand. Now very gently drain the water out until you reach the very end. At a certain point, you will observe the formation of a pear-shaped drop which will fall in case of a slight disturbance. Capture a close-up image of the drop and transfer it to a computer for analysis (as described in Appendix A.1). Measure its dimensions using ImageJ online (https://ij.imjoy.io/) (see Fig. 2).

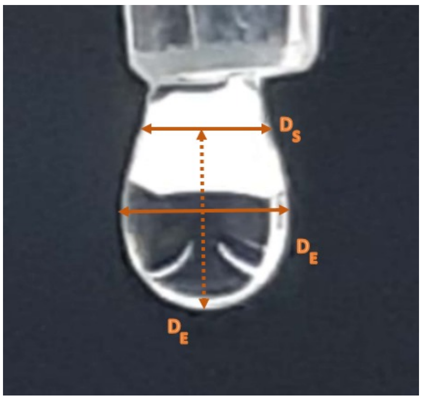


Figure 2: Dimensions of a water pendant drop.

These dimensions can be directly plugged into the following formula.

$$\gamma = \frac{\Delta\rho g D_E^2}{H} \tag{1}$$

The parameters in Eq.1 are summarized below (Table 1)

γ	Surface Tension	N/m
$\Delta\rho$	Difference in density between the liquid and the air	kg/m^3
g	Acceleration due to gravity	m/s^2
D_E	Maximum diameter of the pendant drop	m

Table 1: Variables for surface tension equation.

Furthermore, H is a dimensionless function, defined as

$$\frac{1}{H} = a\left(\frac{D_S}{D_E}\right)^b \tag{2}$$

where D_S is the diameter of the pendant drop at a distance D_E from the bottom edge of the drop, $a = 0.345$ and $b = -2.5$.

Now before you perform this experiment, there are a few things that should be considered.

1. Make sure that the pendant-shaped drop is the largest possible drop that could have been formed.
2. By repeating this procedure a few times, you will have an idea of how large the drop can be and you will be able to recognize a drop that is not properly formed.
3. Do take care of units. Surface tension is measured in Newtons per meter. So, in Eqs. (1) and (2), take care of using proper units that carry over to the final result.

Glass tubes are very fragile. Do not keep your eyes too close to them while experimenting. In case of breakage, do not touch any sharp edges.

What does the data say?

[Q 1] . From your data and Eq.1 and Eq. 2, estimate the surface tension of water? What is it's uncertainty?
[Q 2] . Try repeating this with various liquids and compare them with standard values. Table2 lists the surface tension of common liquids.

Substance	Surface Tension (millinewton/meter)
ethanol	22.4
chloroform	26.7
water	72.8
mercury	486

Table 2: The surface tensions of various substances at 25C

مزے کا مشاہدہ

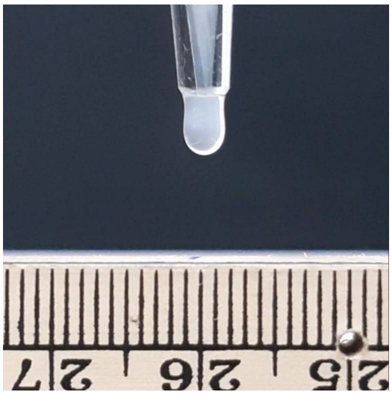


Figure 3: Methanol

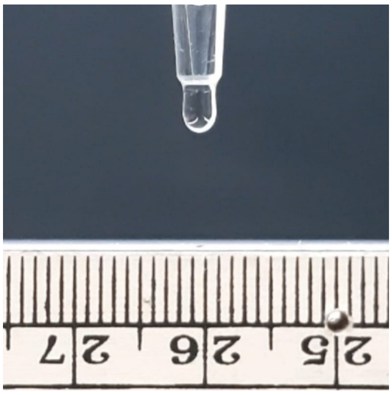


Figure 4: Ethanol

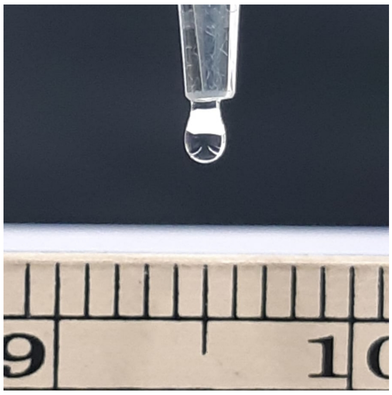
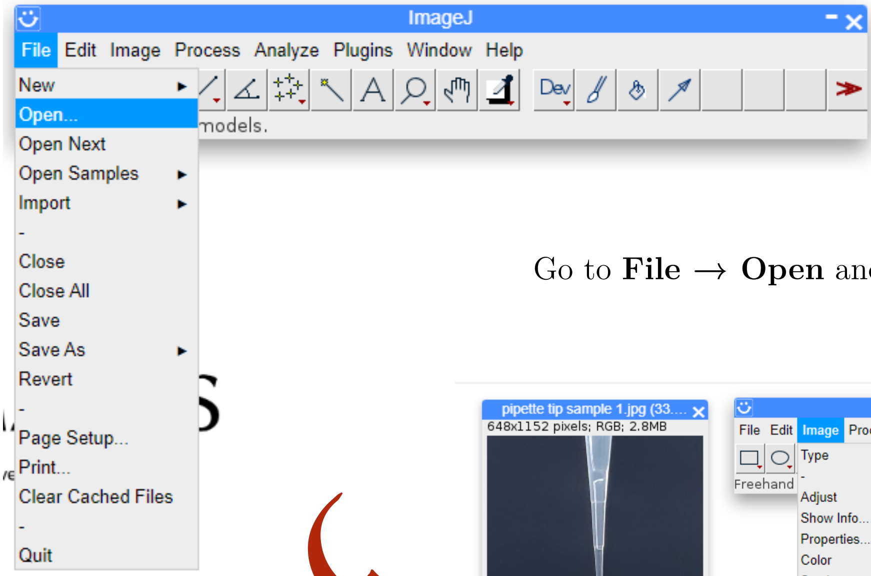


Figure 5: Water.

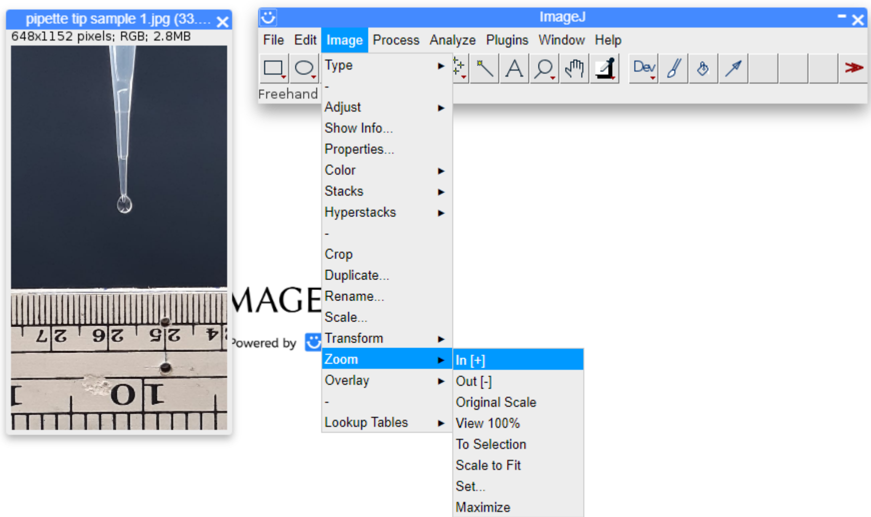
یہ تین مختلف مائع کے قطروں کی تصویریں ہیں۔

A Appendix

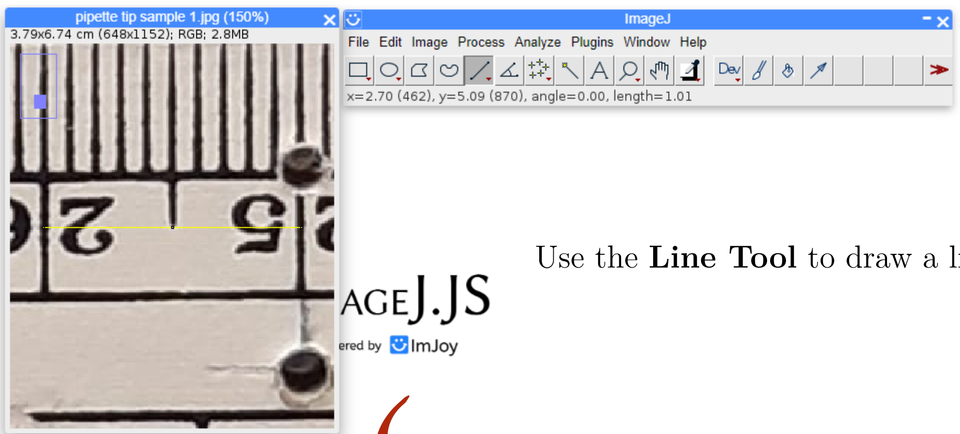
A.1 ImageJ.Js Software



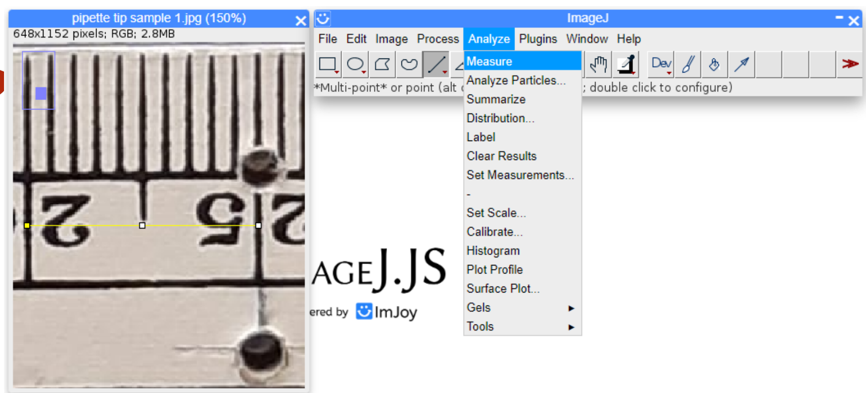
Go to **File** → **Open** and chose your image.



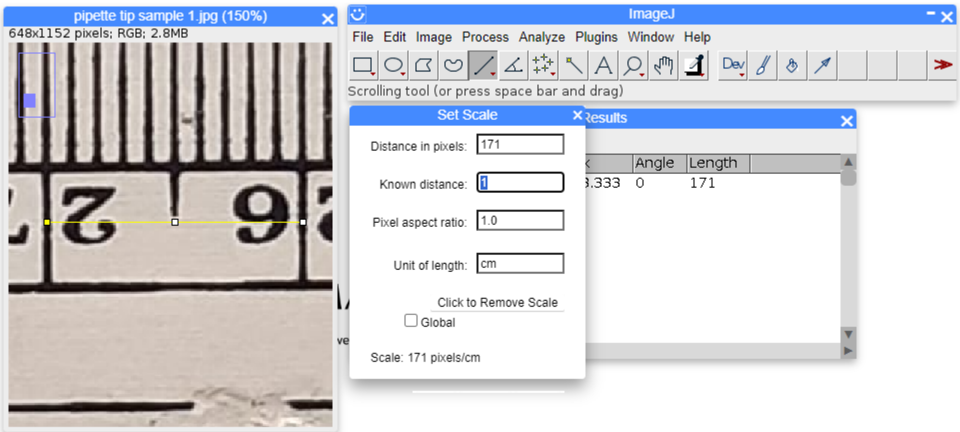
Zoom into the scale by clicking on **Image** → **Zoom** → **In** [+] .



Use the **Line Tool** to draw a line representing 1 cm.

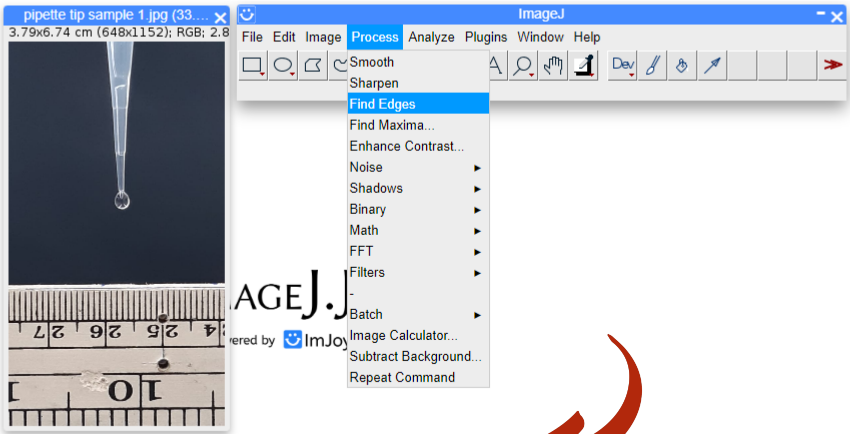


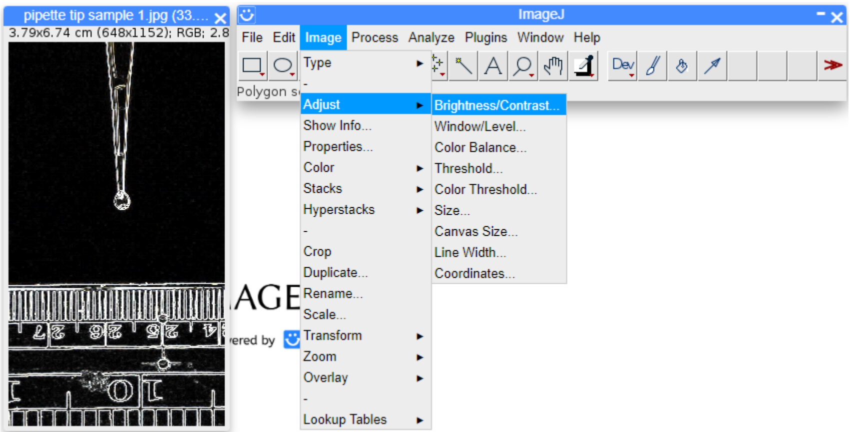
Go to Analyse → **Measure** that gives you measurements in pixels, and calibrate by using **Set Scale**.



Set the value of Known distance and units then press enter.

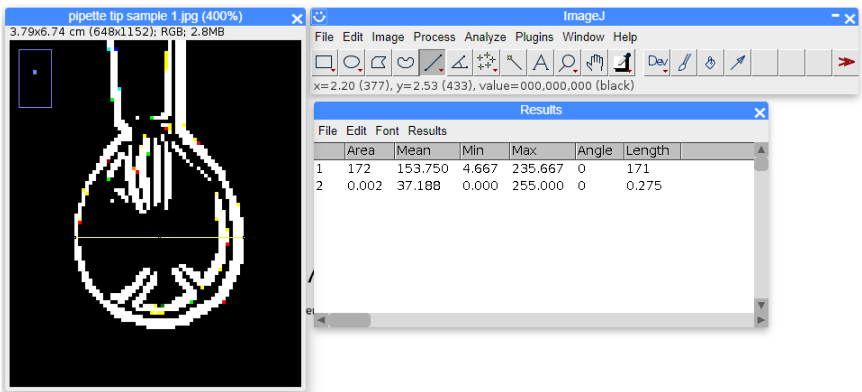
To make the image more clear, adjust the contrast by going to **Image** → **Adjust** → **Brightness/Contrast**.



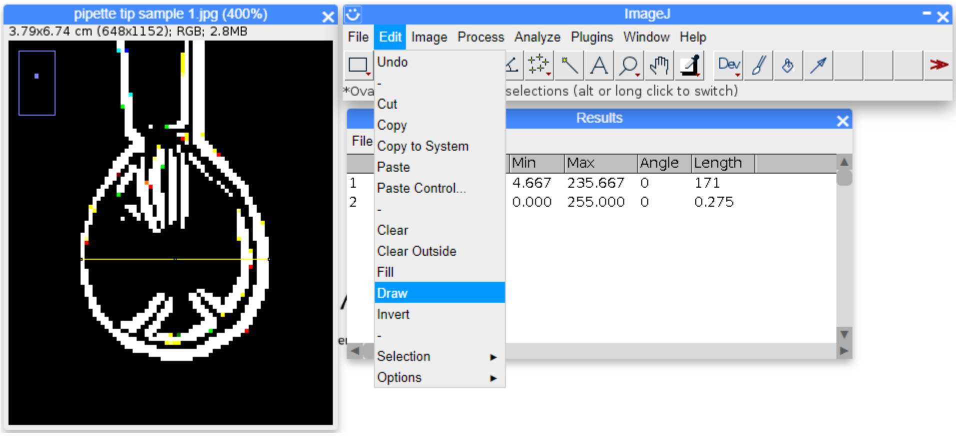


Observe the pendant drop and locate its maximum diameter. Use the Line Tool to draw this diameter. Make sure you zoom in and extend this line to the **center of the edges of the drop**. Go to **Analyse** → **Measure**. This is the value of D_E .

Go to **Edit** and click on **Draw** to make this line permanent.



Go to **Edit** and click on **Draw** to make this line permanent.



Now you can collect the data from **Results** dialogue box.