Surface tension: soap bubbles

Surface tension

Surface tension γ is defined in newtons per metre. Wall tension in a rubber membrane is defined in the same way. Imagine a rectangular sheet of rubber that hangs from a horizontal rail and supports a uniform 10 kg bar along the lower edge. If the bar is 50 cm long the wall tension is 100/0.5 = 200 N/m.

Soap bubble pressure

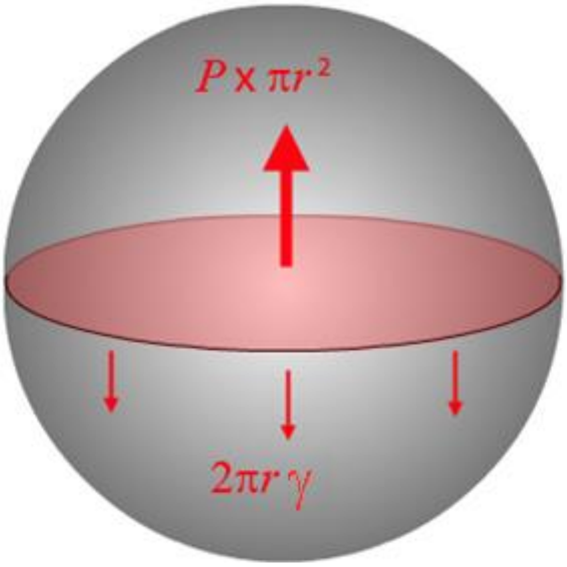


Fig 1 – A soap bubble in two halves.

The top half of the bubble is forced upwards by the internal gauge pressure and held down by the tension along the circumference. The force acting on the top hemisphere is the excess internal pressure P (*gauge pressure*) multiplied by the cross sectional area πr^2. The surface tension force acting along the circumference is $2\pi r\gamma$ where gamma γ is in newtons per metre.

$$\pi r^2 P = 2\pi r\gamma$$

and …. $$P = 2\gamma/r$$

The surface tension γ is constant (independent of the radius) for water drops and soap bubbles. Gauge pressure is inversely proportional to the radius.

For a soap bubble the relationship is ...

$$P = 4\gamma/r$$

... because there are two water surfaces.

Measuring soap bubble pressure

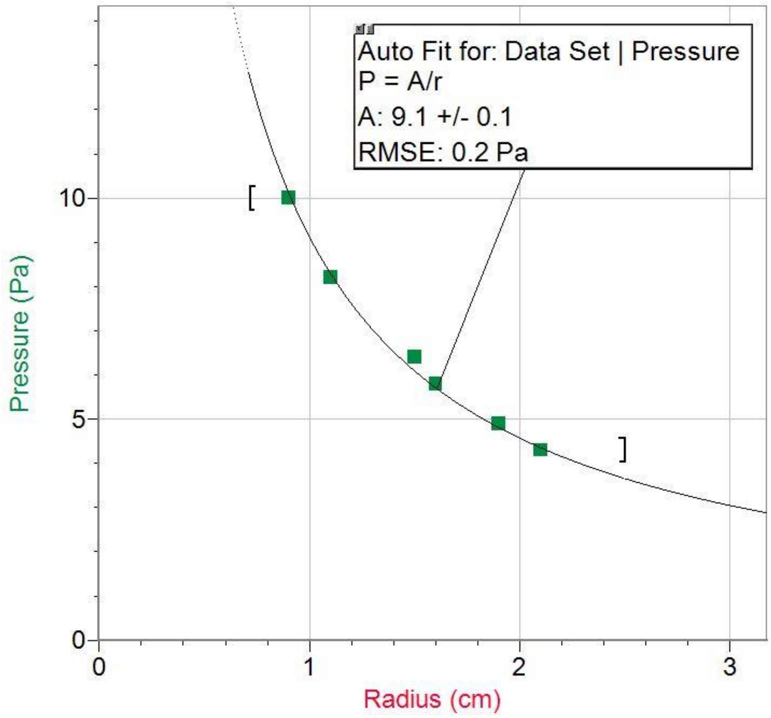
The pressure in a soap bubble is of the order of 10 pascals. A Vernier pressure sensor, or even a water manometer, cannot be used to reliably measure this pressure, and another way must be found.

Fig 2 – improvised apparatus for measuring soap bubble gauge pressure.

The pressure chamber is an open bottle top supported on a clamp stand with a vertical tube. The circular bottom edge of the pressure chamber is under the water in a shallow pan that rests on a digital balance. The white vertical tube is hollow, allowing air to be added or removed with a syringe to alter the radius of the bubble. With this diameter of pressure chamber a two cm bubble exerts the weight of approximately four grams on the water surface. Converting this weight to newtons allows the pressure in the bubble to be found as *F/A.*

To attach a hanging bubble to the yellow tube the end is dipped in detergent solution. The diameter of the bubble is adjusted by adding or removing air through the clear aquarium hose.

The bubble diameter can be measured by superimposing a mm scale on a photograph, being careful to ensure that the scale and the bubble were the same distance from the camera when the photographs were taken. Plotting pressure against radius (Graph 1 below) gives an inverse function as expected.



Graph 1 – gauge pressure versus radius for a typical soap bubble.

The surface tension γ is $Pr/4$. For this typical detergent solution gamma is 23 milli-newtons per meter (mN/m) independent of the radius of the bubble and the thickness of the soap film. The accepted value of surface tension for water without detergent is 73 mN/m. The presence of detergent, soap, and/or glycerin lowers the surface tension and makes it possible to blow bubbles.

A question

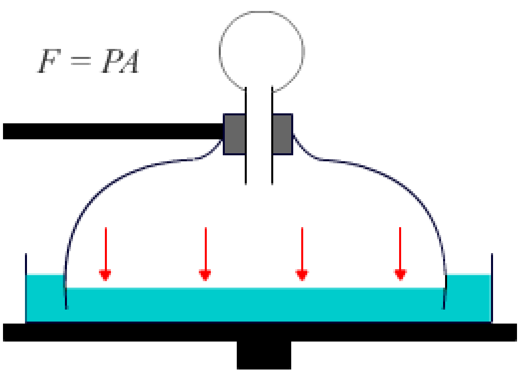


Fig 3 – the bubble at this small radius is unstable and quickly collapses. .

A soap bubble with a diameter of less than 1 cm is unstable on the apparatus shown and rapidly contacts. Why might that happen? How could the apparatus (figure 2) be modified to measure pressure in smaller bubbles?

A stable soap bubble

Soap bubbles exposed to the open air rapidly evaporate. When they become very thin the usual colored reflections disappear. The bubble becomes almost invisible just before it bursts. The near disappearance is a demonstration of the different phase changes at open and closed boundaries that prevent the reflection of waves from very thin films, but that is a story for another time.

Long-lasting soap bubbles can be blown in a atmosphere saturated with water vapour.

To demonstrate this …

Put a little water in a three liter PET bottle and shake it to saturate the air inside. Blow a soap bubble in the bottle. Close the bottle and put it aside.

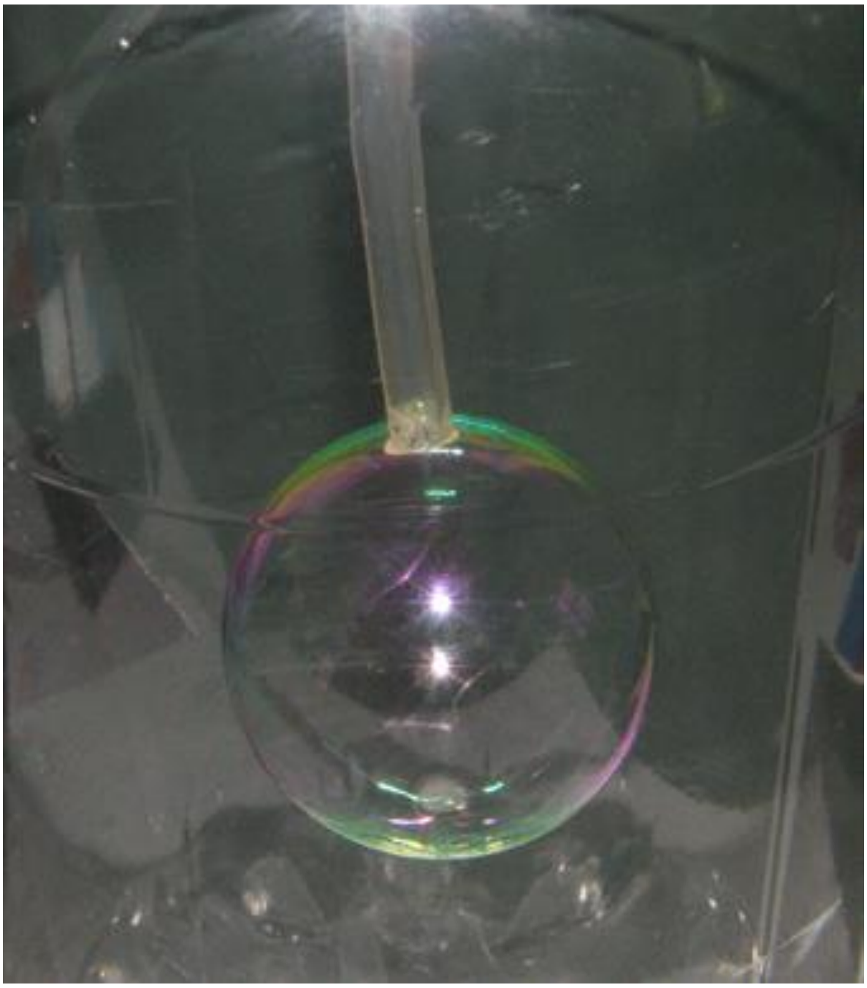


Fig 4 – a soap bubble in a closed PET bottle: five hours old at the time the image was taken.