PHYSICS IN DAILY LIFE:

BUBBLES AND BALLOONS

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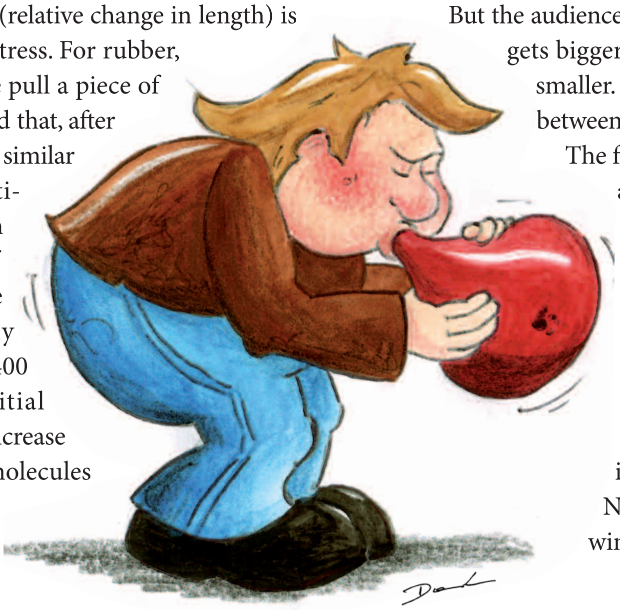
When blowing soap bubbles as kids, we were probably much too fascinated by their beautiful colours to realize that there is some interesting physics going on. For one thing, the very existence of the bubbles demonstrates the concept of surface tension, since the slight overpressure inside the bubble has to be balanced by attractive forces in its 'skin'. And, in the process, it teaches us that, for a given volume, a sphere has the smallest surface area.

Blowing up a rubber balloon reveals some additional interesting aspects. Since the forces involved are much larger, some are easily noticed. We have all experienced that the first stage of blowing up a balloon is the hardest. Once the balloon has reached a certain volume, things get easier. The pressure needed decreases. This is funny, because everyone knows that, if you stretch a piece of rubber, the force required *increases* with length.

To fully understand the behaviour of the balloon, we need to know a bit more about the elasticity of rubber. This turns out to be significantly different to the normal behaviour of a common elastic material, for which Hooke's law holds: strain (relative change in length) is proportional to applied stress. For rubber, things are different. If we pull a piece of rubber band apart, we find that, after an initial rise in the stress similar to Hooke, there is a relatively flat plateau which ranges from strains of about 50 % to 200 %. Here the stress is reasonably constant. Only at about 400 % – four times the initial length – does the stress increase steeply, since the macromolecules making up the rubber become fully stretched.



Now back to the balloon. Remembering the 'plateau' we assume for argument's sake that the 'surface tension' τ (force per unit length) is constant, just like in the case of soap bubbles. If we now consider a spherical balloon to consist of two imaginary halves and write down the force balance between the two halves ($\pi R^2 p = 2\pi R\tau$, with p the overpressure in the balloon), we find that the pressure needed to keep the balloon inflated is inversely proportional to the radius R. This qualitatively explains the fact that blowing-up the balloon gets easier once it has reached a certain size.

This observation calls for a spectacular experiment to amuse your audience. Take two balloons, inflate one of them to roughly one third of its maximum size and the other to two thirds. Attach both balloons to a piece of tubing while keeping the connection between the two closed with your finger. Ask the audience what will happen if you let go and connect both balloons through the tube. Sure enough, the audience expects the balloons to become equally big. After all, this is what happens if you take the two connected *un*inflated balloons and pull them apart: they will both be stretched to the same size.

But the audience is wrong. The big balloon gets bigger and the smaller one gets smaller. It illustrates the difference between force and pressure.

The funny properties of rubber are also at the heart of the remarkable behaviour which we see if we inflate a long, sausage-shaped balloon. We find that two 'phases' coexist at a single pressure. But here the physics is a bit more complicated. Not quite as simple as blowing bubbles. ■