SOAP-BUBBLES,

AND THE FORCES WHICH MOULD THEM.

By C. V. Boys, A.R.S.M., F.R.S. of the Royal College of Science.

(Continued.)

I did not in the last lecture by any direct experiment show that a soap-film or bubble is really elastic, like a piece of stretched india-rubber.

A soap-bubble, consisting, as it does, of a thin layer of liquid, which must have of course both an inside and an outside surface of skin, must be elastic, and this is easily shown in many ways. Perhaps the easiest way is to tie a thread across a ring rather loosely, and then to dip the ring into soap water. On taking it out there is a film stretched over the ring, in which the thread moves about quite freely, as you can see upon the screen. But if I break the film on one side, then immediately the thread is pulled by the film on the other side as far as it can go, and it is now tight (Fig. 19). You will also notice that it is part of a perfect circle, because that form makes the space on one side as great, and therefore on the other side, where the film is, as small, as possible. Or again, in this second ring the thread is double for a short distance in the middle. If I break the film between the threads they are at once pulled apart, and are pulled into a perfect circle (Fig 20), because that is the form which makes the space within it as great as possible, and therefore leaves the space outside it as small as possible. You will also notice, that though the circle will not allow itself to be pulled out of shape, yet it can move about in the ring quite freely, because such a movement does not make any difference to the space outside it.

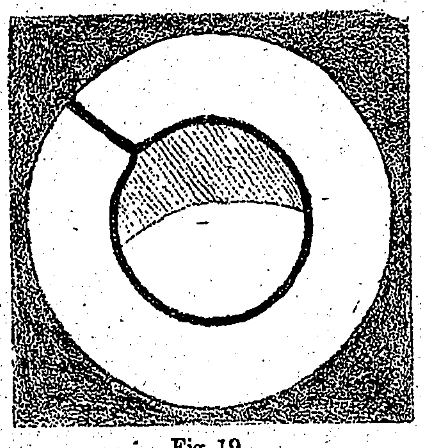

Fig 19.

I have now blown a bubble upon a ring of wire. I shall hang a small ring upon it, and to show more clearly what is happening, I shall blow a little smoke into the bubble. Now that I have broken the film inside the lower ring, you will see the smoke being driven out and the ring lifted up, both of which show the elastic nature of the film. Or again, I have blown a bubble on the end of a wide pipe; on holding the open end of the pipe to a candle flame, the outrushing air blows out the flame at once, which shows that the soap-bubble is acting like an elastic bag (Fig 21). You now see that, owing to the elastic skin of a soap-bubble, the air inside is under pressure and will get out if it can. Which would you think would squeeze the air inside it most, a large or a small bubble? We will find out by trying, and then see if we can tell why. You now see two pipes each with a tap. These are joined together by a third pipe in which there is a third tap. I will first blow one bubble and shut it off with the tap I (Fig 22), and then the other, and shut it off with the tap 2. They are now nearly equal in size, but the air cannot yet pass from one to the other because the tap 3 is turned off. Now if the pressure in the largest one is greatest it will blow air into the other when I open this tap, until they are equal in size; if, on the other hand, the pressure in the small one is greatest, it will blow air into the large one, and will itself get smaller until it has quite disappeared. We will now try the experiment. You see immediately that I open the tap 3 the small bubble shuts up and blows out the large one; thus showing that there is greater pressure in a small than in a large bubble. The directions in which the air and the bubble move is indicated in the figure by arrows. I want you particularly to notice and remember this, because this is an experiment on which a great deal depends. To impress this upon your memory I shall show the same thing in another way. There is in front of the lantern a little tube shaped like a U half filled with water. One end of the U is joined to a pipe on which a bubble can be blown (Fig 23). You will now be able to see how the pressure changes as the bubble increases in size, because the water will be displaced more when the pressure is more, and less when it is less. Now that there is a very small bubble, the pressure as measured by the water is about one quarter of an inch on the scale. The bubble is growing and the pressure indicated by the water in the gauge is falling, until, when the bubble is double its former size, the pressure is only half what it was; snd this is always true, the smaller the bubble the greater the pressure. As the film is always stretched with the same force, whatever size the bubble is, it is clear that the pressure inside can only depend upon the curvature of a bubble. In the case of lines, our ordinary language tells us, that the larger a circle is the less is its curvature; a piece of a small circle is said to be a quick or a sharp curve, while a piece of a great circle is only slightly curved; and if you take a piece of a very large circle indeed, then you cannot tell it from a straight line, and you say it is not curved at all. With a part of the surface of a ball it is just the same—the larger the ball the less it is curved; and if the ball is very large indeed, say 8,000 miles across, you cannot tell a small piece of it from a true plane. Level water is part of such a surface, and you know that still water in a basin appears perfectly flat, though in a very large lake or the sea you can see that it is curved. We have seen that in large bubbles the pressure is little and the curvature is little, while in small bubbles the pressure is great and the curvature is great. The pressure and the curvature rise and fall together. We have now learnt the lesson which the experiment of the two bubbles, one blown out by the other, teaches us.

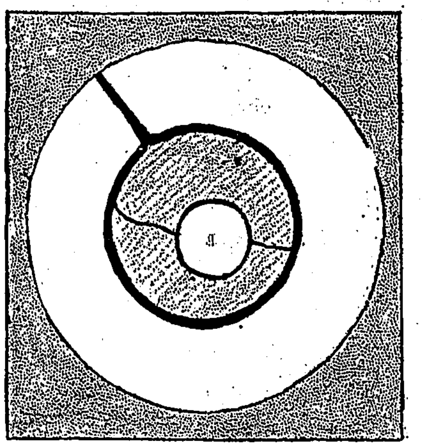

Fig 20.

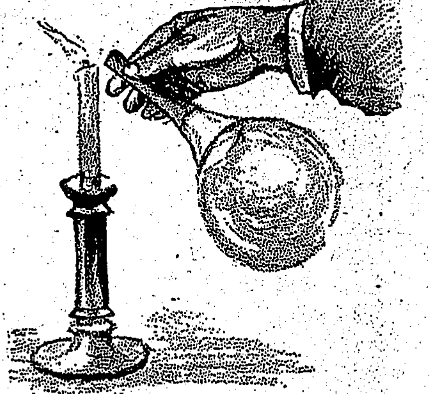

Fig 21.

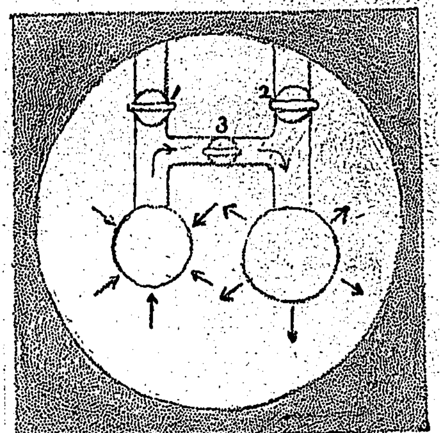

Fig 22.

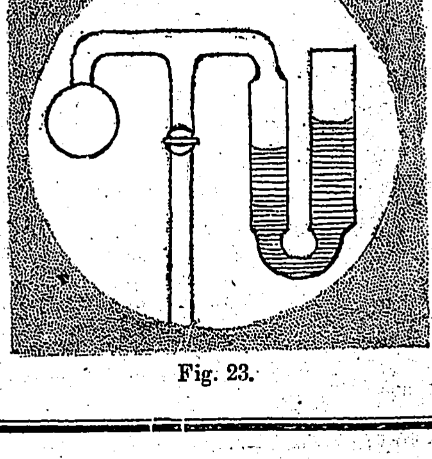

Fig. 23.

A ball or sphere is not the only form which you can give to a soap-bubble. If you take a bubble between two rings, you can pull it out until at last it has the shape of a round straight tube or cylinder as it is called. We have spoken of the curvature of a ball or sphere; now what is the curvature of a cylinder? Looked at sideways, the edge of the wooden cylinder upon the table appears straight, *i.e.*, not curved at all; but looked at from above it appears round, and is seen to have a definite curvature (Fig. 24). What then is the curvature of the surface of a cylinder? We have seen that the pressure in a bubble depends upon the curvature when they are spheres, and this is true whatever shape they have. If, then, we find what sized sphere will produce the same pressure upon the air inside that a cylinder does, then we shall know that the curvature of the cylinder is the same as that of the sphere which balances it. Now at each end of a short tube I shall blow an ordinary bubble, but I shall pull the lower bubble by means of another tube into the cylindrical form, and finally blow in more or less air until the sides of the cylinder are perfectly straight. This is now done (Fig. 25), and the pressure in the two bubbles must be exactly the same, as there is a free passage of air between the two. On measuring them you see that the sphere is exactly double the cylinder in diameter. But this sphere has only half the curvature that a sphere half its diameter would have. Therefore the cylinder, which we know has the same curvature that the large sphere has, because the two balance, has only half the curvature of a sphere of its own diameter, and the pressure in it is only half that in a sphere of its own diameter.

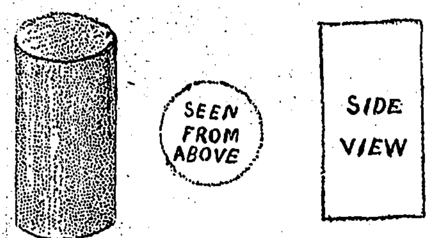

Fig. 24.

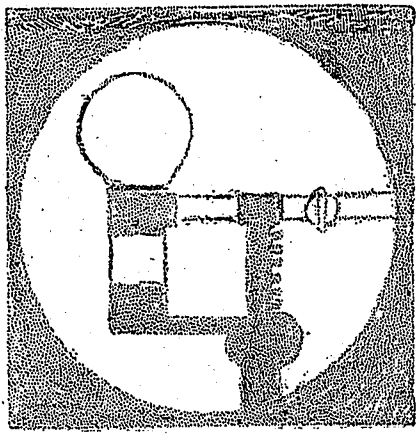

Fig. 25.

I must now make one more step in explaining this question of curvature. Now that the cylinder and sphere are balanced I shall blow in more air, making the sphere larger; what will happen to the cylinder? The cylinder is, as you see, very short; will it become blown out too, or what will happen? Now that I am blowing in air you see the sphere enlarging, thus relieving the pressure; the cylinder develops a waist, it is no longer a cylinder, the sides are curved inwards. As I go on blowing and enlarging the sphere, they go on falling inwards, but not indefinitely. If I were to blow the upper bubble till it was of an enormous size the pressure would become extremely small. Let us make the pressure nothing at all at once by simply breaking the upper bubble, thus allowing the air a free passage from the inside to the outside of what was the cylinder. Let me repeat this experiment on a larger scale. I have two large glass rings, between which I can draw out a film of the same kind. Not only is the outline of the soap-film curved inwards, but it is exactly the same as the smaller one in shape (Fig. 26). As there is now no pressure there ought to be no curvature, if what I have said is correct. But look at the soap-film. Who would venture to say that that was not curved; and yet we had satisfied ourselves that the pressure and the curvature rose and fell together. We now seem to have come to an absurd conclusion. Because the pressure is reduced to nothing we say the surface must have no curvature, and yet a glance is sufficient to show that the film is so far curved as to have a most elegant waist. Now look at the plaster model on the table, which is a model of a mathematical figure which also has a waist.

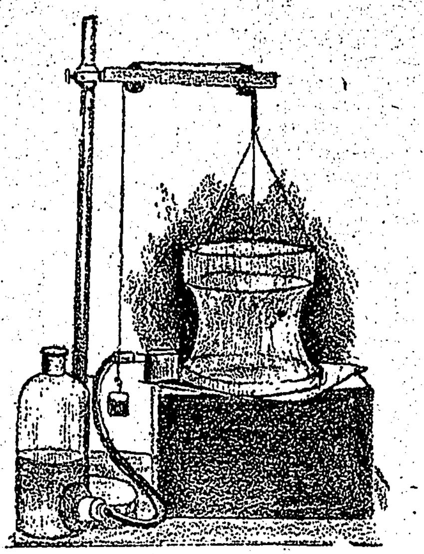

Fig. 26.

(To be Continued.)

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ONE THING NEVER DIES.

To-day, upon Palm Sunday, Jesus comes riding into Jerusalem in the midst of palm-branches and hosannas. Next Thursday, He is prostrate in Gethsemane. Next Friday, He is hanging on the cross. Next Sunday, He is rising from the tomb. The great experiences come quick on one another. Joy crowds on sorrow, sorrow presses on the steps of joy. To each comes the quick end. Each is but born before it dies. But one thing never dies—the service of His Father, the salvation of the world, the sum and substance of His life! Set upon that, with His soul full of that, joy comes and pain comes, and both are welcomed and dismissed with thankfulness because their coming and their going bring the end for which He lives more near.—*Phillips Brooks.*

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A QUEER BOY.

He doesn't like study; it 'weakens his eyes,'
But the 'right sort' of book will ensure a surprise.
Let it be about Indians, pirates, or bears,
And he's lost for the day to all mundane affairs;
By sunlight or gaslight his vision is clear.
Now, isn't that queer?

At thought of an errand he's 'tired as a hound,
Very weary of life and of 'tramping around;'
But if there's a band or a circus in sight,
He will follow it gladly from morning till night.
The showman will capture him some day, I fear,
For he is so queer.

If there's work in the garden, his head 'aches to spilt,'
And his back is so lame that he 'can't dig a bit.'
But mention baseball, and he's cured very soon;
And he'll dig for a woodchuck the whole afternoon.
Do you think he 'plays possum?' He seems quite sincere;
But—isn't he queer?

—*St. Nicholas.*