The Case of the Floating Needle

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In discussing the phenomenon of surface tension, practically all textbook writers cite the fact that an ordinary sewing needle may be made to float on water, the usual inference being that forces due to surface tension account for the support of the needle. Some writers suggest that the needle should be rubbed through a slightly oiled cloth or slightly oily fingers before attempting the experiment in order that the water should not wet the needle. One might be led to infer that this slight oiling will facilitate flotation.

The above assumptions have been questioned by Frederick E. Beach,[1] and quantitative experimental evidence is cited to support an entirely opposing view. In the Beach experiment a hollow circular torus was substituted for the needle and it was shown that in this case there were three forces which contributed to the support of the torus: (1) the buoyancy due to the water displaced by the immersed portion of the torus, (2) the buoyancy due to the water displaced from the space over the bared portion of the ring, and (3) the upward components of the surface tension. Beach also contended that oiling the metal reduced the surface tension factors and cited experimental data to support his contention.

Objections have been raised to the Beach conclusions because of the nature of the oil used (oleic acid and crude oil) and because a torus was substituted for a cylindrical needle.

In view of these objections and counter-objections it was decided to reinvestigate the phenomenon and attempt to arrive at quantitative results with a cylindrical object.

First, several needles were successfully floated and the contour of the water surface was studied by magnifying glasses and photographs which were greatly enlarged. Portions of the needles were cut off in order that end views could be obtained. Due to a lack of proper facilities for making microphotographs the results obtained by this method were not conclusive.

By subsidiary tests it was ascertained that the contact angle for water on clean aluminum was essentially the same as that for clean steel. In each case the angle of contact was so nearly 90° that this value was considered approximate. Later measurements taken from enlarged photographs confirmed this conclusion.

In order that data of a quantitative character might be obtained, a hollow aluminum cylinder 10.0 cm. long and .860 cm. diameter was stopped at each end and this cylinder was found to float readily. Cross sectional photographs were made of this floating cylinder. These photographs were enlarged and projected from a slide upon a screen from which satisfactory measurements could be made. Figure 1 shows an

[1] Beach, F. E., 1928. Am. Journ. Scin. **16**:

enlargement of an end view of the floating cylinder. Figure 2 illustrates the measurements which were taken from a large projection of Figure 1.

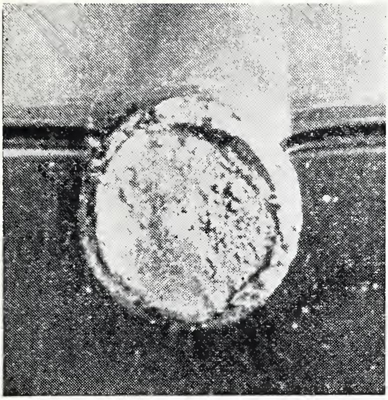

Fig. 1

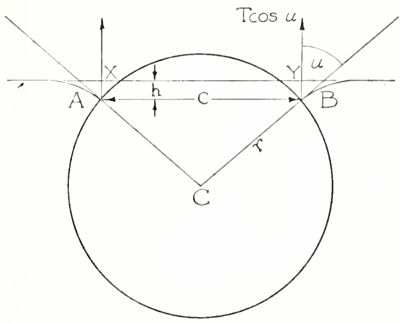

Fig. 2

It is obvious that there are three forces supporting such a floating object: (1) The buoyant force of the water displaced by the submerged portion below the chord AB. (2) The upward force due to the depth of the contact points A and B below the free surface. This is approximately equal to the weight of the water which would fill the section ABXY. (3) The upward components of the surface tension.

The data from which the calculations were made are: mass of cylinder 6.150 grams, temperature of water 70° F., giving T = .0727 g per cm., CB, the radius of the cylinder, .430 cm., arc AB = .78 cm., AX, the height of free surface above contact point, .05 cm., length of cylinder 10 cm. The angle made by the surface tension vector with its upward component, was computed from arc AB and the radius to be 51°58′.

From these data the three upward forces were computed and found to be:

(1)	Mass of water displaced by portion below AB............	5.029 g.
(2)	Mass of water displaced by portion above AB............	.339 g.
(3)	Upward force due to surface tension....................	.896 g.
	Total upward force.....................................	6.264 g.

The error is slightly over 1 per cent and is well within the expected value.

In the foregoing calculation it was assumed that the angle of contact is approximately 90°. This assumption could not have been in error by more than two or three degrees and this would not affect the results to an extent beyond experimental limitations.

As regards small solid steel needles which may be slightly oiled it may be pointed out that if the oiling could be so slight that it would not affect the water it would be entirely possible to support the needle by the forces due to surface tension alone provided the needle has a diameter not to exceed .5 mm. For unit length of such a needle the equation for equilibrium, assuming the surface tension vector acts vertically and that the specific gravity of steel is 7.5, is

$$7.5\pi r^2 = 2\ T.$$

Assuming T = .070 grams per cm., we obtain r = .025 cm. For any solid steel needle larger than this a buoyant force must be added.

Conclusions

1. It is possible to float an oiled steel needle for a short while at least by surface tension alone if the needle is very small (.5 mm. diameter or less).

2. In most cases heavy objects floating on water are wet by the water and are thus partially supported by forces due to the displaced water and partially by the upward components of the surface tension.

3. Oiling a needle slightly will not make it float more readily but it will permit the forces due to surface tension to act unaided save for the relatively small buoyant forces due to the water displaced, and if the needle is small enough it will ride in a hollow trough as is contended by some textbook writers.

4. In most cases it is most likely that a cylindrical needle floating on water is acted upon by all three forces cited in the Beach experiment and confirmed in the present case.

5. It is recognized that a solid cylindrical needle of density seven or eight times that of water is not analogous to the case of a hollow needle such as was used in this experiment and since the needles referred to in physics textbooks are solid steel needles it is hopd that further study may be made which will throw more light on the specific case of a solid needle floating on water.