



XXXV. On an optical test for angles of contact

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in which

$$\left. \begin{aligned} \psi_1''' &= \log \frac{8a}{b} - \frac{11}{6} \\ \psi_2''' - \psi_1''' &= \frac{1}{2} + \frac{1}{4} - \frac{1}{3} - \frac{1}{5} \\ \psi_3''' - \psi_2''' &= \frac{1}{4} + \frac{1}{6} - \frac{1}{5} - \frac{1}{7} \\ \psi_4''' - \psi_3''' &= \frac{1}{6} + \frac{1}{8} - \frac{1}{7} - \frac{1}{9} \\ . \quad . \quad . \quad . \quad . \quad . \quad . \end{aligned} \right\}$$

The above series are suitable for short coils. (J) and (K) are convergent for all lengths. (L) and (M) converge only if $b < 2a$.

XXXV. *On an Optical Test for Angles of Contact.*

By Prof. A. ANDERSON, M.A., and J. E. BOWEN, M.A.*

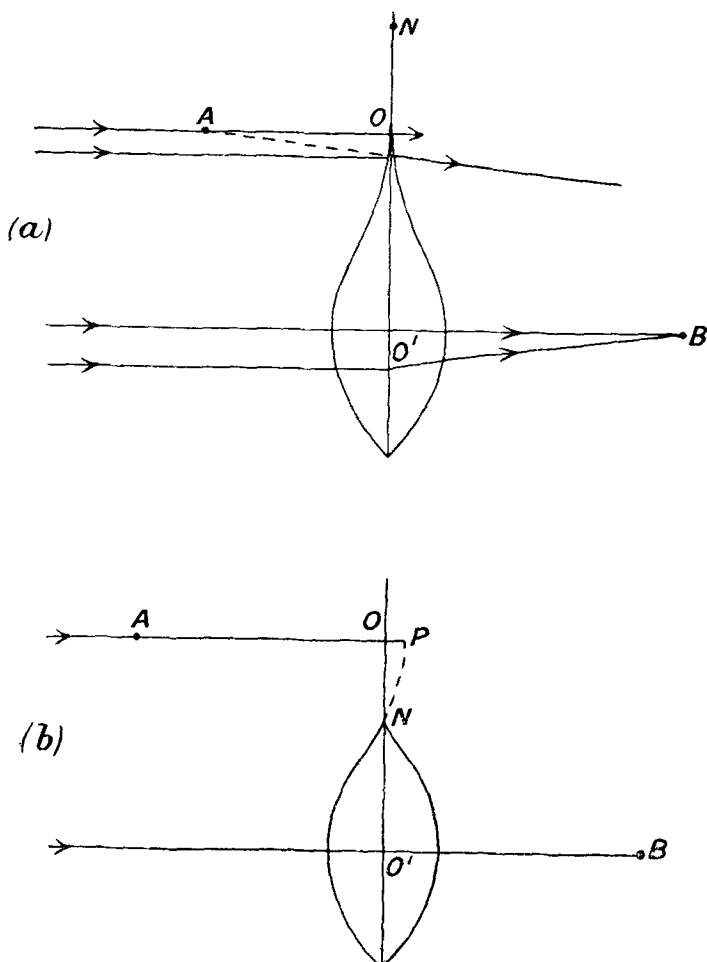
IN the February Number of the 'Philosophical Magazine' we gave a method of determining surface-tensions from observations on the heights to which liquids rise in tubes, which is free from corrections of any kind, and the accuracy of which depends entirely on the capabilities of a measuring microscope. We showed how, by plotting curves giving the relation between the radius of the tube and the radius of curvature at the centre of the meniscus, the angle of contact could be deduced. The curves obtained for water and some other liquids showed that—at least, very approximately—this angle was zero.

The following experiment was designed to test directly whether any angle of contact differing from zero really exists in the case of water and some other liquids which were examined. If a rectangular piece of very thin glass be dipped in a liquid and then held in a vertical plane with two of its edges horizontal, there will be a long cylindrical drop attached to it. Its cross-section or the appearance it presents when looked at endwise is one of the forms represented in the figure (fig. 1).

* Communicated by the Authors.

Fig. 1 (a) is drawn on the supposition that the angle of contact is zero. It will be seen that the drop forms two cylindrical lenses, one convex with centre at the point O' , the other (only the lower half of which is present) being

Fig. 1.



concave with centre at O , the point where the glass plate is tangential to the contour of the drop. The upper edge of the drop may be along the line through O perpendicular to the plane of the paper, or may be higher up at some point N . If a

collimator with its axis horizontal and with a horizontal slit be placed to the left of the drop, parallel light will fall perpendicular to the glass plate as shown in the figure, and the concave lens will form an image of the slit, which will be a straight line through O perpendicular to the plane of the paper, and in the same horizontal plane as the corresponding line through O. If now a low-power microscope be placed to the right of the drop with its axis along OA, the image of the slit formed at A can be seen and arranged to coincide with the horizontal cross-wire of the microscope. If the microscope be now moved back through a distance AO it will be focussed on the glass plate, and the image in the microscope of the upper edge of the drop should either coincide with the horizontal cross-wire of the microscope or it should be necessary to raise the microscope vertically to make it do so.

If an angle of contact existed, the drop would present the appearance of fig. 1 (*b*). The continuation of one side of the drop has been dotted in to the point P, where it would become vertical; and it will be observed that in this case the centre of the lens O which is in the same horizontal plane as P is above the upper edge of the drop. Thus after focussing the microscope on A, getting the image to coincide with the horizontal cross-wire, and then moving it back through the distance AO so as to focus on the glass plate, the microscope must be lowered a distance ON to get the image of the upper edge of the drop to coincide with the cross-wire.

The microscope used was the Bailey & Smith microscope used in the previous experiment (*loc. cit.*). This was capable of horizontal and vertical motions, and was arranged with axis along the line of parallel light and its horizontal motion along this line. A clean microscope slide-cover was used as the glass plate and the liquids examined were those of the former experiment—water, glycerine, olive-oil, and turpentine. In all of these when the drop was freshly formed a perfectly straight image of the slit was seen, and to get the image of the upper edge of the drop (sometimes marked by a line of extremely minute air-bubbles) to coincide with the cross-wire when the microscope was brought back the microscope had to be raised. The image of this edge was not straight. As evaporation went on the upper edge came down to the same level as A (which of course also moved, both vertically and in a horizontal direction perpendicular to the plate); and as evaporation proceeded further the image became curved and took the shape of the upper edge of the drop. No indication of the state of things represented in fig. 1 (*b*) could be

observed. Hence it was concluded that the angles of contact in the cases examined were zero.

As the liquid on the two sides does not evaporate at quite the same rate, the upper edges on the two sides do not always coincide: thus a better examination can be made if only one side of the plate be wet and only half the drop shown in the figure be formed.

If the argument used above is correct, it is possible to use the experiment as a rough method of measuring surface-tensions. To do this we consider the convex lens also, which has its centre at O' , and which brings the parallel light to a focus at B .

Let $a = OA$.

$b = O'B$.

h = vertical distance between OA and $O'B$.

r_1 = radius of curvature of each face of concave lens
(assuming curvature the same).

r_2 = radius of curvature of face of convex lens.

μ = refractive index of liquid.

ρ = density of liquid.

p_1 = pressure inside liquid at O .

$p_2 =$ " " " " O' .

π = atmospheric pressure.

T = surface-tension of liquid.

Treating the lens as thin,

$$\frac{1}{a} = (\mu - 1) \frac{2}{r_1}, \quad \frac{1}{b} = (\mu - 1) \frac{2}{r_2},$$

$$p_2 = \pi + \frac{T}{r_1},$$

$$p_1 = \pi - \frac{T}{r_2};$$

$$\therefore p_2 - p_1 = T \left(\frac{1}{r_1} + \frac{1}{r_2} \right) = \frac{T}{2(\mu - 1)} \left(\frac{1}{a} + \frac{1}{b} \right).$$

But

$$p_2 - p_1 = g\rho h;$$

$$\therefore T = 2g\rho(\mu - 1)hab/(a + b).$$

If only one side of the plate is wet with the liquid, the formula becomes

$$T = g\rho(\mu - 1)hab/(a + b).$$

As the microscope was fitted with verniers for both horizontal and vertical movements, the readings were easily taken. The method is, of course, not capable of great accuracy, owing to the changes taking place in the drop due to evaporation. In the case of a liquid which evaporates quickly (*e. g.* turpentine) the readings must be taken very rapidly.

The following are some measurements taken in this way, which appear to be sufficiently close to show that the argument is correct :—

Water.

$a = \cdot 644$	$b = \cdot 544$	$h = \cdot 392$	$T = 75\cdot 6$
$\cdot 764$	$\cdot 673$	$\cdot 350$	$78\cdot 2$
$\cdot 932$	$\cdot 66$	$\cdot 294$	$73\cdot 5$

Turpentine.

$a = \cdot 674$	$b = \cdot 331$	$h = \cdot 151$	$T = 26\cdot 9$
$\cdot 576$	$\cdot 396$	$\cdot 15$	$28\cdot 2$
$\cdot 661$	$\cdot 354$	$\cdot 148$	$27\cdot 4$

Glycerine.

$a = \cdot 443$	$b = \cdot 287$	$h = \cdot 370$	$T = 74\cdot 9$
$\cdot 435$	$\cdot 344$	$\cdot 337$	$75\cdot 2$
$\cdot 358$	$\cdot 400$	$\cdot 344$	$75\cdot 5$
$\cdot 367$	$\cdot 338$	$\cdot 392$	$74\cdot 4$
$\cdot 308$	$\cdot 369$	$\cdot 382$	$74\cdot 5$

a , b , h are in cm., T in dynes per cm. It will be noticed that though the method gives values for water and turpentine in the neighbourhood of those generally accepted, the values for glycerine, though consistent with each other, are too high. This may be due to the fact that the glycerine drop is much thicker than either of the others, and the formula for thin lenses may not apply; or it may be due to the rapid absorption of aqueous vapour from the air.

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