# SURFACE TENSION

REFERENCES

Most introductory Physics texts (e.g. M. Sternheim and J. Kane, *General Physics*, D. Halliday and R. Resnick, *Physics*).

INTRODUCTION

This experiment is intended to give you an understanding of:

- The concept of the phenomenon of surface tension,

- Three methods of measuring surface tension, along with a comparison of and critical evaluation of these methods,

- What affects surface tension and its measurement,

- The use of certain pieces of apparatus such as a tensiometer, a travelling microscope and a hydrometer. A hydrometer measures the density of liquids and is available at the **R**esource **C**entre.
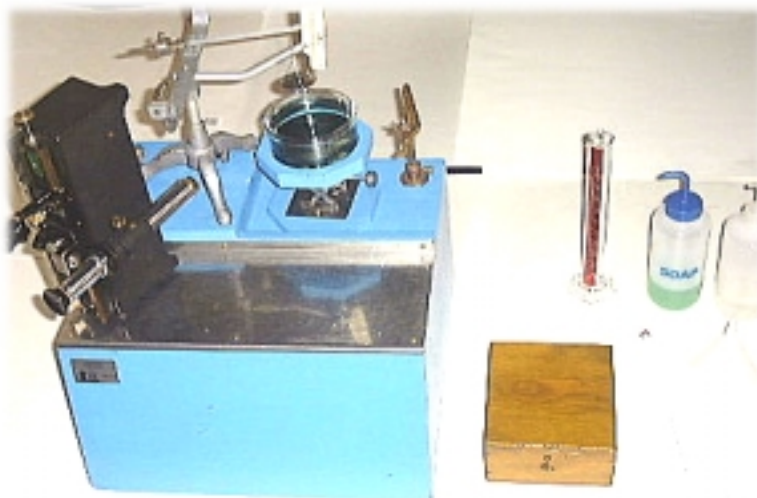
Each molecule of a liquid experiences forces of attraction exerted on it by all its neighbours. A particular molecule in the interior of the liquid experiences a large number of forces in all directions from its neighbours and the net force on it is very nearly zero. But, if a molecule is at the free surface of the liquid, the net force acting upon it is directed downwards since there are more closely spaced neighbours in the liquid below than in the vapour above. Work must therefore be done in order to bring a molecule from the interior of the liquid to the free surface and the surface consequently possesses a larger energy than the interior. Thus, the surface behaves in some respects as if it were a stretched film or membrane under tension, and the surface tension, *T* is defined as F/ℓ where *F* is the force which the surface exerts on a line of length ℓ in the surface; *F* is directed at right angles to the line considered. The surface tension of a liquid depends very markedly upon the presence of impurities in the liquid and upon temperature. Cleanliness is imperative if meaningful values of *T* are to be determined; in particular, avoid handling with your fingers any surface which will be in contact with the liquid.

THE TECHNIQUE

There are three methods available to you to determine the surface tension of a liquid. The first two involve the use of a tensiometer and the third involves the measurement of the rise of a liquid in a capillary tube.

- The first method works well for soap solutions or other liquids that will form self-supporting bubbles. It will soon become apparent to you that this technique does not work for water. Suspend a rectangular wire frame from the hook under the scale pan of the balance and adjust the counterpoise so that the balance beam is approximately horizontal when the lower edge of the frame is just immersed in the liquid. (Avoid froth on the liquid and support the dish at a convenient height). Then depress the beam of the balance until the upper edge of the frame is submerged, and release it gently so that a film forms over the upper edge of the frame and the beam is held below its equilibrium position by the double film of the liquid stretching on each side of the wire to the surface of the liquid. Allow the firm to drain a few seconds and note the final steady reading of the pointer. Then break the film; observe that the beam rises. Add weights M to the scale pan until the pointer is depressed to the same reading as that noted when it was held down by the film. The added weights must therefore equal the force Mg exerted by the surface tension forces in the film when they were acting on the wire. Therefore

$$Mg = 2\ell T$$

  where ℓ is the length of the upper part of the wire frame measured to the inside of the wire, and the factor of two enters because the film has two surfaces, (This method could be subject to errors due to buoyant forces on the wire frame in the liquid. Ascertain for yourself whether it is necessary to make additional corrections for these buoyant forces.)

- The second method to find T will work for most liquids. Use the glass microscope slide in place of the wire frame. Clean the slide with a kimwipe and thereafter do not touch the lower edge of the slide with your fingers. Dip the slide in the liquid and adjust the balance until the film between the bottom edge of the glass and the surface of the liquid is just on the point of breaking. Note the reading of the pointer, remove the dish containing the liquid and dry the slide carefully with a kimwipe. Determine, as before, the mass M required to depress the pointer to the same reading and calculate T. Note the finite thickness of the slide. Note also the temperature of the water.

- In the third method, the surface tension of a liquid can be determined by capillary ascension. When a capillary (available at the **R**esource **C**entre) of internal radius r is placed vertically so that one end of the capillary is immersed in the liquid, the liquid is observed to rise to a height, h, in the tube. If the liquid wets the walls of the tube, the liquid is "pulled" up by the surface tension force, $T(2\pi r)$, acting on the "line" represented by the internal circumference of the tube, $2\pi r$. When equilibrium is achieved this force is balanced by the weight of the liquid supported in the tube. Thus,

$$T(2\pi r) = \rho(\pi r^2 h)g$$

where ρ is the density of the liquid. Focus a vertically-moving travelling microscope on the meniscus and adjust it until the cross-hair appears tangential to the meniscus; record the reading of the vernier. Then lower the microscope until the cross-hair is aligned with the liquid level. You will have to work out how to determine the liquid level precisely. Note that it is important that the height of the liquid measured is the *equilibrium* height. Also note that the state of cleanliness of the walls of the capillary tube has a serious effect on the surface tension measurement.

THE EXPERIMENT

You are provided with distilled water, tap water and soap solution. Measure the surface tension of these liquids by as many ways as you can. Your interpretation should contain a critical evaluation of the three methods and should evaluate under what conditions each method is most valid.

In performing your measurements a number of cautions need to be observed. These include the careful and clean handling of weights and wires using tweezers, making sure that parallax is not affecting your readings and being sure that you have all needed quantities recorded such as temperatures and densities of the liquids.

(jv - 1988)

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