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The siphon

A Potter and **F H Barnes**
Department of Natural Philosophy
The University
Edinburgh

The siphon has been known since early times as a simple and effective device for transferring liquid from a higher to a lower level and is still widely used. Despite this, considerable confusion exists as to how the siphon works and a survey of elementary textbooks (here 'elementary' refers to GCE O and A level standard) yields a number of conflicting accounts. Many are in terms of hydrostatic principles which cannot apply and, in addition, atmospheric pressure is postulated as an essential agency in most accounts, including those given by the standard dictionaries. Few books point out that it is the cohesion of the liquid rather than the pressure of an external atmosphere which is crucial to the working of a siphon. Some American college texts discuss the siphon and give a correct theory although generally in terms of non-viscous fluids. It is unusual for more advanced texts to discuss the siphon, for it is only a particular case of the general problem of pipe flow which has been the subject of thorough investigation. We have written this article because we are concerned that misleading interpretations of the siphon are still current even though much is known about the physics of pipe flow and the properties of liquids.

We begin with a survey of the 'hydrostatic' theories, following this with the dynamic theory for an 'ideal' nonviscous liquid. We modify our 'ideal' theory to take account of the viscous nature of liquids and then give some experimental results. Finally we attempt to analyse the factors underlying the working of the siphon and suggest a possible theory.

Hydrostatic theories

A typical account of the siphon given in elementary text books might read as follows.

Referring to figure 1, p_B equals p_0, where p_0 is the pressure of the surrounding atmosphere and p_B is the pressure at point B in the liquid. Since B and E lie on the same horizontal level (strictly, on the same gravitational equipotential), p_B equals p_E. The pressure p_F of the liquid at F equals $p_E + \rho gh$ and therefore also equals $p_0 + \rho gh$ where ρ is the density of the liquid. Thus p_F is greater than the external pressure, and the liquid flows out of the tube. In order to prevent a vacuum forming in the tube more liquid, pushed in by the atmospheric pressure, enters at A. Another common account begins by saying that p_B equals p_0 and p_F equal p_0. Then, by consideration of heights of liquid, it is argued that the pressure at C must be greater than the pressure at D, and this pressure difference causes the liquid to flow. This account is incorrect. If the liquid is stationary p_C must always equal p_D. If the liquid flows and we apply the principles of fluid dynamics, we still find that the pressures at points on the same horizontal level are equal if the pipe is of uniform bore and we neglect viscous losses.

The first account given above is correct when no flow occurs but its limitations as a theory for a working siphon are obvious since it describes a static condition. The siphon is essentially a device involving fluid flow and it is desirable that our theory should allow us to make some quantitative predictions such as, for example, the dependence of the rate of flow of liquid on the height h.

Dynamic theory

The discussion below considers the flow of fluids in

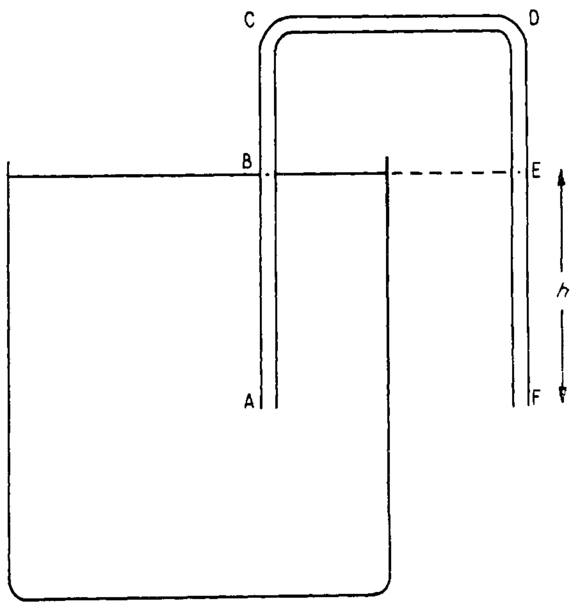

Figure 1 *Diagram of a siphon.*