ELEMENTARY HYDROSTATICS: WITH NUMEROUS EXAMPLES

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HYDROSTATICS.

SECTION I.

PRELIMINARY DEFINITIONS AND EXPLANATIONS.

1. DEF. A *fluid* is a collection of material particles so situated in contact with each other as to form a continuous mass, and such that the application of the slightest possible force to any one of them is sufficient to displace it from its position relative to the rest.

That part of *Statics*, where a fluid appears as the principal means of transmission of force, is termed *Hydrostatics*. The law of that transmission must, like the law of transmission by a rigid body, by a free rod or string, or by contact of surfaces, &c. be established by experiment.

The mutual forces called into action by the contact of surfaces are in Statics called *pressures:* this term is used in the same sense in Hydrostatics, where it is applied to denote the forces of resistance, which adjacent particles of the fluid exert, either upon one another, or upon rigid surfaces in contact with them.

2. If in the side of a vessel, containing fluid upon which forces are acting, a piston be placed, the pressure exerted upon it by the fluid particles with which it is in contact, would thrust it out, unless a force sufficient to counteract this pressure were applied to the back: this counteracting force is of course exactly the measure of the pressure of the fluid upon the piston. It is not diffi-

cult to conceive that, generally, the magnitude of this pressure would be different for different positions of the piston in the sides of the vessel; inasmuch as the portions of the fluid which it would touch at those different places, would not necessarily be similarly circumstanced, and would not therefore require for the maintenance of their equilibrium that the piston should exert the same force upon them: when, however, the pressure for *every* such supposed position of the piston, wherever taken, is the same, the fluid is said to press *uniformly;* and when not so, its pressure is said to be not uniform.

Again, it is clear that the pressure upon the piston in any given position must vary with the magnitude of its surface, and if this were reduced to a mathematical point the pressure *upon* it would be, strictly speaking, absolutely nothing, because the surface pressed is nothing; but even in this case the conception of the pressure *at* the point is perfectly definite; it signifies the capability or tendency which the fluid there has to press, and which, if existing over a definite area, would produce a definite pressure; and this view of it leads us to the following usual definition of its measure.

The pressure at any point of a fluid is measured by the pressure which would be produced upon a unit of surface, if the whole of that unit were pressed uniformly with a pressure equal to that which it is proposed to measure.

3. It is usual to represent this measure of the pressure *at* a point by the general symbol p; and whenever it is said that a surface, in contact with a fluid and containing A units of area, is pressed uniformly with a pressure p, it is meant that the pressure of the fluid *at* every point of it, measured as above defined, is equal to

p units of force: hence if P be the pressure which the fluid exerts *upon* this surface A, since the pressure is *uniform*, and therefore the actual pressure *upon* each unit is p, the pressure upon the A units must be A times p, or

$$P = pA.$$

According to the usual convention, by which a square foot is taken to be the unit of area, and one pound weight the unit of force, the numerical value of p would represent pounds.

It may be here remarked, that as P is of four linear dimensions, being the measure of a moving force, and A is of two, therefore p must be of two dimensions.

4. In the foregoing explanation of the meaning of the term "pressure at a point" in a fluid, the point has been assumed to be in contact with a rigid surface, which was supposed to be the subject of the pressure; now if we consider any portion of fluid, within a larger mass and forming part of it, no force but that of resistance can be exerted upon it by the surrounding fluid; for we may imagine it to be isolated from the rest by an excessively thin enveloping film, which will manifestly produce no disturbance among the particles of either portion of the fluid, because its existence neither introduces new forces nor destroys any of those which are acting; further, this film may be supposed rigid, without affecting the relative positions or equilibrium of the particles forming the interior and exterior portions of fluid: but under this hypothesis the pressure at any point, of either the interior or exterior fluid, which is in contact with the rigid film acquires the meaning given above, and as the introduction of the film in no way

alters the actions of the portions of fluid upon one another, we thus arrive at the conclusion that different portions of a mass of uniform fluid only press against each other in the same way as they would against rigid surfaces of the same form, and therefore the term "pressure at a point" means the same thing whether the point be within a fluid or be in one of its bounding surfaces*.

5. This last conclusion with regard to the action of different portions of the same fluid upon one another is of considerable importance in the solution of Hydrostatical problems; as by it we are justified, whenever it concerns us to investigate the pressures exerted by a surrounding fluid upon an included portion, in replacing this portion by a conterminous solid. It is generally convenient to take for such a purpose the solid which would be formed by supposing the constituent particles of the portion of fluid, which it is wanted to replace, to become by any means rigidly fixed in their *relative* positions and to be still affected by the same external forces as before: it is manifest that such a solid could not differ from the fluid which it replaces, as regards its action upon the surrounding fluid, for it would itself be identical with it in every way, were it not for the circumstance that its

* The analogy between "pressure at a point" in a fluid, and "velocity at any instant" of a moving particle, and between their respective measures, is too striking to escape the notice of the student; both terms are abstractions employed for the purpose of avoiding the constant use of the periphrasis, which is given once for all in the definitions of their measures. Perhaps this view of the case would be more apparent if the pressure at a point were defined to be the limiting ratio between the pressure exercised upon a small area taken about that point and the area itself, as this area is indefinitely diminished: at any rate such a definition would considerably simplify the investigations of Arts. 13 and 14.