TREATISE ON HYDROSTATICS AND HYDROMECHANICS, PART II

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A TREATISE

ON

HYDROSTATICS

AND

HYDRODYNAMICS

PART II

BY

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PREFACE.

THE present volume on Hydrostatics and Hydrodynamics was written by the author as a supplemental part to his Elementary Treatise on Hydrostatics, and was completed in the year 1880.

The author was unable during his lifetime to publish this work, being 81 years old when completed. He entrusted the manuscript to my care, requesting me to do so after his death.

The manuscript is therefore published with as little alteration as possible. In fact the only alterations that have been made are found from page 207 to page 222, where the modern names of chemical substances are used.

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PREFACE.

THE sciences of Hydrostatics and Hydrodynamics are founded like other physical sciences on experimental determinations of the properties of bodies; solid, liquid and gaseous.

In discussing the ordinary problems of the rest and motion of fluid bodies, the simple laws or properties of fluids are required to be known, but when we attempt to solve the higher problems of the motions of *fluids* we find that the nature or constitution of fluids must be considered as known also. In this manner it was found by Lagrange that in proceeding analytically by the older rules for the motion of bodies, there was required an additional equation for the solution of problems of hydrodynamics; and he formed this equation on the theory that whilst fluids remain continuous, an elementary portion may change its form, volume, and density, provided the mass remains constant. This equation is called *the equation of continuity*[1]. The theory of sound, the problem of resistances, and the phenomena of diverging and converging streams of elastic fluids are still unsolved by this method. The theory of continuous fluids is consequently insufficient for the true solution of hydrodynamical problems.

The doctrine of the atomic constitution of bodies and the necessary consequence that the motion of fluids consists of the motion of their constituent atoms or molecules, of which each is capable of motion independently of the others, requires us to consider them as congeries of atoms or molecules, each being capable of motion amongst the others on the application of the slightest force or additional force to it.

[1] *Mécanique Analytique*, Vol. 2, p. 338.

When a body is at rest, and equilibrium exists, the atoms or molecules must be in symmetrical arrangement, and if then a displacement is impressed upon any one and when the cause of displacement ceases if the atom or molecule returns to its first position, then the equilibrium is stable and the body a solid body; if it remains in its displaced position, then the equilibrium is neutral and the body a fluid body; but if the atom or molecule moves further from its first position, the equilibrium is unstable and the body ready to change its state, and might be explosive. Soft, viscid and semifluid bodies may be considered to be in intermediate states, having in large masses more or less of the properties of fluids, and in small masses those of solids, as capillary attraction.

It is argued that if ice, water, and steam have the same material particles and that they are in contact in ice, then unless by some most improbable rearrangement they cannot be so in steam, and that porosity must be an admitted property of material bodies. The principle of the impenetrability of matter arises from the evident impossibility of two solid bodies occupying the same space at the same time; and this must apply to their smallest solid particles; but with the property of porosity at the same time, since they are permeated by heat, electricity, &c.

Dr Thomas Young in his lectures on Natural Philosophy has a most complete and learned discussion, "On the essential properties of matter" in his Lecture XLIX. In discussing the property of impenetrability, he arrives at the conclusion—"Besides this porosity there is room for the supposition, that even the ultimate particles of matter may be permeable to the causes of attractions of various kinds, especially if these causes are immaterial: nor is there anything in the unprejudiced study of physical philosophy that can induce us to doubt the existence of immaterial substances; on the contrary we see analogies that lead us almost directly to such opinion."—"We see forms of matter differing in subtilty and mobility under the names of solids, liquids and gases; above these are the semi-material existences which produce the phenomena of electricity and magnetism, and either caloric or a universal ether; higher perhaps are the causes of gravitation, and the

immediate agents in attractions of all kinds, which exhibit phenomena apparently still more remote from all that is compatible with material bodies, and of these different orders of beings the more refined and immaterial appear to pervade freely the grosser."

The discussion leads to the conclusion that there are in the Universe different kinds or orders of existences, substances, entities, essences or beings; which we may conveniently speak of as material, æthereal and spiritual existences or substances; but when we wish to be correct should restrict the word matter to bodies which possess the characteristics of *mass, inertia,* and therefore *weight,* by the law of universal gravitation; but these cannot be attributed to all substances.

Nearly seventy different kinds of undecompounded matters, or simple material substances, are already discovered in the materials of the earth's crust. How many remain still undiscovered we cannot guess. We have no means of knowing how many æthereal substances exist in the universe; and with respect to the spiritual existences we can only conclude that they must be very numerous.

The agent which is the cause of the phenomena of electricity we conclude to be æthereal because it cannot pass or act through a perfect vacuum, and the causes of chemical elective affinity may be so also. The causes of magnetism, of light and heat, and of gravitation, acting through dense bodies as well as through a vacuum, we may conclude to be spiritual existences.

The following passage from Dr Young's lecture is well worth remembering, for it applies to the present times as much as it did to his own times :—" It has been of late very customary to consider all the phenomena of nature as derived from the motions of the corpuscles of matter, agitated by forces varying according to certain intricate laws, which are supposed to be primary qualities, and for which it is a kind of sacrilege to attempt to assign any ulterior cause. This theory was chiefly introduced by Boscovich, and it has prevailed very widely amongst algebraical philosophers, who have been in the habit of deducing all their quantities from each other by mathematical relations, making, for example, the force a certain function or power of the distance, and then imagining that its origin is

sufficiently explained; and when a geometrician has translated this language into his own, and converted the formula into a curve, with as many flexures and reflections as the labyrinth of Dædalus, he imagines that he has depicted to the senses the whole procedure of nature. Such methods may often be of temporary advantage, as long as we are contented to consider them as approximations, or classifications of phenomena only; but the grand scheme of the universe must surely, amidst all the stupendous diversity of parts, preserve a more dignified simplicity of plan and of principles than is compatible with these complicated suppositions."

The relation of heat to the magnitudes of all bodies requires to be considered, and as also being the cause of fluidity in fluid bodies it becomes necessary to discuss some of the properties of heat in treatises on hydrostatics. The nature of heat is also an appropriate subject for study at the same time.

The cause of heat was named *caloric* by the great French chemist Lavoisier, and as an æthereal or spiritual fluid to be an essential part of all matter in the state in which we meet with it. This conception of the cause of heat and temperature was so consonant to the phenomena of chemistry that it has generally been accepted by chemists as the true theory. It was not however the first hypothesis of the nature of heat. Sir John Herschel in his treatise on "Heat" in the *Encyclopædia Metropolitana* says, "The vibratory hypothesis which is usually attributed to Bacon is thus explained in his own words, 'Calor est motus expansivus, cohibitus, et nitens per partes minores.' Perhaps this is the same as if he had said that caloric is a force which is opposed to molecular attraction; and that heat is the effect of a vibration produced by these conflicting forces. Of this opinion were also Boyle and Newton: whilst Rumford and Sir Humphrey Davy have been its most recent and able advocates."

The argument, which was considered as unanswerable and decisive by Count Rumford, Sir Humphrey Davy, and Dr Thos. Young, and is also at the present time by the advocates and teachers of the mechanical theory of heat, is this, that an unlimited amount of heat can be produced by friction between