ELEMENTARY IDEAS, DEFINITIONS AND LAWS IN DYNAMICS

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PREFACE.

THE following pages are not intended for the use of very young students, but rather for those who, having taken such a course of physics as is now common in schools which prepare boys for college, would fit themselves to deal with the fuller developments or wider generalizations of physical science.

Such students might be referred at once to Clerk Maxwell's *Matter and Motion;* but they would find in that book some things too difficult for them, and they would hardly be led by it to make for themselves those experiments which are for many students the only means of attaining sound and vital notions of general truths. Moreover, the term inertia, which the student is sure to encounter in his reading of physics and is likely to find used in more than one sense, is ignored by Maxwell in the treatise mentioned.

The author of this pamphlet had the good fortune to find the Harvard Physical Club, at its formation last spring, willing to devote several meetings to the discussion of his manuscript. By far the greater part of this discussion was given to the pages dealing with inertia and mass, and the final *form* which those pages have taken is due very largely to criticisms and suggestions made at these meetings. It must be understood, however, that the author takes the sole responsibility for the teachings of the pamphlet.

My thanks are due to several friends who have assisted in preparing the manuscript for the press or in reading the proof-sheets.

E. H. HALL.

CAMBRIDGE, *October* 18, 1886.

ELEMENTARY IDEAS, DEFINITIONS, AND LAWS, IN DYNAMICS.

Introductory. — Almost every beginner in the study of Physics has difficulty in mastering the ideas necessary for an intelligent handling of problems involving the consideration of masses undergoing change of motion. A large part of this difficulty arises from the fact that in such problems the student needs to use with a strict meaning terms that he habitually uses with a loose meaning, or with several meanings. The text-books do not always succeed in setting him right in this particular, and he may suffer for years under disadvantages which a few hours of study should remove. Popular significations need not be called *incorrect* by the scientific man, but frequently they are different from the scientific significations. Even scientific men do not always agree about definitions.

An attempt is here made to define and correlate the ideas associated with the words Weight, Inertia, Mass, Force, Work, and Energy. In this process any one of these terms may be used before it is defined, in cases where the popular use of the term is sufficiently exact for the immediate purpose. One word, however, Force, which must appear very frequently in the following pages, has been used so loosely, in scientific as well as in popular writings, that it is well to give at once the following provisional definition: Force is a Push or a Pull.

Weight. — It is one of the commonest facts of observation that bodies when unsupported fall toward the earth. Whether the earth really attracts them, or whether they are by some other means impelled toward it, we do not know. The notion that the earth attracts them accounts perfectly well for the observed facts, and as no other hypothesis that has been proposed accounts for them equally well, physicists hold and teach as an extremely convenient and useful theory, if not a final fact, that bodies fall because they are pulled downward by the earth's attraction. With this explanation we shall henceforth speak of this supposed attraction as if it were an established fact.

It is another fact of observation that the earth revolves upon an axis, and it can easily be shown by experiment that the effect of this revolution must in some measure neutralize the earth's attraction, so as to make the apparent attraction slightly different from the real. The Weight of a body, in the scientific sense, is a *force*, which force is the *apparent attraction* of the earth.

Since the earth is not a perfect sphere, since it is composed of different materials in different places, and since bodies near the poles revolve in a smaller daily circle than bodies nearer the equator, we might expect the weight of a body to depend somewhat upon its place on the earth's surface. Observation shows this to be true. A given body will stretch a spring-balance more in regions far north or far south than in regions near the equator.

At the equator and the poles the weight of bodies is directed toward the earth's centre. At other parts of the earth's surface weight is directed nearly, but in general not exactly, toward the earth's centre. Evidently the free surface of still water or any other liquid must be everywhere at right angles to this force. Such a surface is called a *level* surface.

We ask here a question which will prove very important when we come to speak of Inertia. When a body is placed upon a level surface in such a manner that it does not tend, from mere imperfect balancing, to roll or tip, does the weight of the body, as we have defined weight, either help or hinder the body's motion in any direction along the level surface, save by causing friction with the surface? All experience goes to show that it does not do so; that, in fact, no force in a given direction either directly helps or directly hinders motion in a line at right angles to the direction of the force. We shall therefore take it as settled, that upon a level surface the *weight* of a body affects motion only by causing friction.

Suspending a body by a fine wire we can get rid of nearly all friction except that offered by the air. When a body is so suspended and is hanging at rest, any swing imparted to it will involve some ascent by the body against the earth's pull; but if the wire used for the suspension be a long one, the curved incline up which the body moves in leaving its equilibrium position will be at first very gradual. Experience has taught every one that the pull required to move a body, with uniform velocity, along such an incline, is very small compared with that force which we call the weight of the body.

Inertia. — All this being understood, let us suspend a fifty-pound ball by a long wire, attach a string to the ball, and, taking the free end of the string in the hand, suddenly move the hand horizontally away from the ball. As soon as the string is drawn straight, one feels that the hand is *pulling*, that it encounters a *resistance*, which is offered in some way by the ball at the other end of the string. If the hand be jerked violently, this pull may become so great as to break the string, even if the latter is strong enough to bear easily the whole weight of the fifty-pound ball.

How can we account for this observed resistance? Per-