A TREATISE ON THE THEORY OF FRICTION

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BY

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PREFACE.

The Theory of Friction, considered as a part of Rational Mechanics, has hardly received the attention which it deserves. Even in the most complete systematic treatises, the space accorded to its discussion is small, compared with that bestowed upon questions in which the hypothesis of perfect smoothness has been assumed as the basis of the investigation. And it seems probable that many students have been led to regard the discussion of this force, less as a part of Rational Mechanics, than as a correction to be applied before the investigations of that science can be made practically useful. Such an idea, if it exist, is a complete mistake. The theory of friction is as truly a part of Rational Mechanics as the theory of gravitation. The force with which this theory is concerned is subject to laws as definite, and as fully susceptible of mathematical expression, as the force of gravity. And even if the imperfection of our analysis should render impossible the actual solution of the problems which are presented to us in this theory, such an imperfection, which is purely mathematical, cannot affect the right of the theory itself to be considered as a part of Rational Mechanics. Neither is this right affected, even if it be shown that the laws usually assigned to the force of friction are not mathematically true for any known substance. Rational Mechanics, considered as a hypothetical science, takes no account of this fact, and for the reality and usefulness of the conclusions it is only necessary that these laws should be approximately true, as they certainly are. Throughout the present treatise the proportionality of the force of friction to the pressure is assumed. This law, though not mathematically correct, represents the facts with sufficient exactness to serve as the basis of a theory whose results approximate closely to the truth. The adoption of a more complicated law would have greatly enhanced the mathematical difficulties of the theory, yet without giving results mathematically coincident with facts. Here, as in all other applications of Rational Mechanics to actual phenomena, we must be content with approximations to the truth.

The plan of the present work may be shortly stated as follows :—

Commencing with the two great classes of force, namely, moving and resisting forces, the Author has, in Chap. I., pointed out the important distinction between them, consisting in the fact that while forces of the first class are independent of the forces by which they are opposed, those of the second class vary in magnitude or direction, or both, with these opposing forces.

Two kinds of resisting force are then especially noticed, namely, 1. Forces by which the geometrical conditions, connecting with each other the several parts of a material system, may be replaced, without making any change in its motion (or rest, if it be at rest). These forces are distinguished by the name "geometrical forces," and their true character is pointed out. 2. Friction. The laws which govern this force are then given, and the action of a rough surface upon a particle which rests or moves upon it is expressed by means of a geometrical conception which is (so far as the Author is aware) due to Mr. Moseley. The important differences between the friction of rest and the friction of motion are now noticed for the first time.

In Chap. II. the Author has considered the problem of equilibrium, noticing especially the *indeterminateness* which often appears in questions where friction is one of the acting forces. This apparent indeterminateness is traced to its source, namely, the abstractions of Rational Mechanics; and it is shown that if the conditions of the problem be stated as they really exist in nature, no such indeterminateness will appear. Various examples of the problem of equilibrium, both of particles and of solid bodies, are given.

Chap. III. treats of *extreme* positions of equilibrium, those, namely, in which the smallest diminution in the friction acting at some one or more points of the system will destroy its equilibrium. In such cases it becomes an important question: What points of the system are in extreme positions? or, in common words, what points of the system are so situated, that any diminution of the *roughness* of the surfaces which are there in contact would cause the system to *slip?*

Proceeding to investigate this question, the Author has given some examples, in which it admits a simple solution. The general problem is then examined by the help of certain analytical Lemmas, and rules are given for its solution. But the great length of the process would make this solution very difficult, except for the simplest cases.

A special section is devoted to extreme positions of a solid body.

Chap. IV. treats of the motion of a particle, or system of particles. Here the indeterminateness before noticed in statical problems appears again, and is particularly considered.

A special section is, on account of the importance of the question, devoted to the problem of *initial* motion, and another to the motion of a particle upon a surface which is itself moving.

Chap. V. treats of the motion of a solid body, with special reference to the case in which the motion is a pure rotation round an axis fixed or variable, and some general propositions are given applicable to this case. The case of a body which rolls without sliding, and the initial motion of a solid body, are also specially considered.

Chap. VI. treats of the distinction, peculiar to the present subject, between *necessary* and *possible* equilibrium. It is shown, by a consideration of the difference between statical and dynamical friction, that there are certain positions of a system in which equilibrium *must* exist, and others in which it *may* exist, but does not *necessarily* exist; and a method is given by which these two kinds of equilibrium may be distinguished from each other. This, although a question of equilibrium, and therefore appearing to belong properly to Statics, could not have been considered at an earlier part of the inquiry, inasmuch as, like the problem of stable and unstable equilibrium, it is solved by principles essentially dynamical.

In Chap. VII. the Author has considered the principles on which we may attempt to remove the ambiguity so constantly occurring in problems in which friction is one of the acting forces. He has shown that this can