KINEMATICS OF MACHINES.

CHAPTER I.

INTRODUCTORY CONSIDERATIONS.

1. Study of Machines. — In general the study of a Machine involves problems of three distinct kinds. We may first of all consider from a geometrical point of view the motion of any part of the machine with reference to any other part, without taking account of any of the forces acting on such parts. Or, the action of the forces impressed on the parts of the machine, and of the forces due to its own inertia or to the weight of its parts, may be dealt with, and the resulting transformations of energy may be determined. A third branch of the theory of machines treats of the action of these loads and forces in producing stresses and strains in the materials employed in the construction of the machine, and discusses the sizes, forms, and proportions of the various parts which are required either to insure proper strength while avoiding waste of material, or to make the machine capable of doing the work for which it is being designed.

The science dealing with the first-named class of problem is termed the *Kinematics of Machines*, which we may define as being that science which treats of the relative motion of the parts of machines, without regard to the forces producing such motions, or to the stresses and strains produced by such forces.

With this limitation, in the case of almost all bodies forming portions of machines, it is possible to neglect any deformation they may undergo in working, and in studying the Kinematics of Machines we may at once apply to machine problems the results obtained by the study of the motion of rigid bodies. Important exceptions will present themselves to the reader's mind; for example, ropes, belts, and springs cannot be considered kinematically as being rigid, and many mechanical contrivances involve the use of liquid or gaseous material. Such cases as these will be considered later.

By the term *Machine* we may understand a combination or arrangement of certain portions of resistant material, the relative motions of which are controlled in such a way that some form of available energy is transmitted from place to place, or is transformed into another desired kind. This definition includes under the head of Machines all contrivances which have for their object the transformation or transmission of energy, or the performance of some particular kind of work, and further implies that a single portion of material is not considered as a machine. The so-called *simple machines* in every case involve the idea of more than one piece of material.

A combination or arrangement of portions of material by means of which forces are transmitted or loads are carried without sensible relative motions of the component parts is called a *Structure*.

The term *Mechanism* is often used as an equivalent for the word Machine. It is, however, preferable to restrict its use somewhat, and to employ the word to denote simply a combination of pieces of material having definite relative motions, one of the pieces being regarded as fixed in space. Such a mechanism often represents kinematically some actual machine which has the same number of parts as the mechanism with the same relative motions. The essential difference is that in the case of a machine such parts have

to transmit or transform energy, and are proportioned and formed for this end, while in a mechanism the relative motion of the parts only is considered. We may look upon a mechanism, then, as being the ideal or kinematic form of a machine, and our work will be much simplified in most cases if we consider for kinematic purposes the mechanism instead of the machine. Such a substitution is also of the greatest service in the comparison and classification of machines; we shall find in this way that machines, at first sight quite distinct, are really related, inasmuch as their representative mechanisms consist of the same number of parts having similar relative motions, and only differing because a different piece is considered to be fixed in each case.

2. Constrained Motion.—On further consideration of the nature of a Machine as defined above, it will be noted that each part of the machine must have certain definite motions relatively to any other part, such definite motions being repeated again and again during the working of the machine. Thus the motion of a machine-part must be completely *constrained*, that is, the part must be free to move only in the manner desired to produce the required transformation of energy, and for it other unnecessary motions must be rendered impossible. Constrained motion of a body takes place when every point in the body is made to describe some definite and prescribed path. This constraint is effected in general by so forming and connecting the parts that all forces tending to disturb their constrained motion are balanced by stresses set up in the parts themselves. It is assumed, of course, that the machine remains uninjured by such stresses.

3. Pairs of Elements.—The nature of the connection between the parts of a machine will be best understood by taking a simple case and discussing the way in which some form of constrained relative motion of two bodies may be obtained. Suppose, for example, that a piece of material,