NOTES AND EXAMPLES IN MECHANICS: WITH AN APPENDIX ON THE GRAPHICAL STATICS OF MECHANISM

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by Irving P. Church

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NOTES AND EXAMPLES

—IN—

MECHANICS

WITH AN APPENDIX ON THE

GRAPHICAL STATICS OF MECHANISM

—BY—

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SECOND EDITION, REVISED AND ENLARGED

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PREFACE.

THE following pages form a companion volume to the writer's *Mechanics of Engineering*, and contain various notes and many practical examples, both algebraic and numerical, serving to illustrate more fully the application of fundamental principles in Mechanics of Solids; together with a few paragraphs relating to the Mechanics of Materials, and an Appendix on the "Graphical Statics of Mechanism."

Advantage has been taken of the use of preliminary impressions in the classroom to make corrections in the electrotype plates; and it is therefore thought that the present complete edition is comparatively free from typographical errors.

In the Appendix are presented many of the problems of Prof. Herrmann's "*Zur Graphischen Statik der Maschinengetriebe*" in what seems to the writer a clearer form than in the original (for reasons stated on the first page of Appendix). In this part of the work, the text and diagrams not being adjacent, alternate pages have been left blank in such a way that any diagram and its appropriate text can be kept in view simultaneously.

Besides his indebtedness to Prof. Herrmann's work, the writer would gratefully acknowledge the kindness of the Messrs. Wiley in securing a higher order of excellence in the execution of the diagrams than had at first been contemplated.

In references to the writer's *Mechanics of Engineering* the abbreviation M. of E. is used.

CORNELL UNIVERSITY,
ITHACA, N. Y., March, 1894.

PREFACE TO SECOND EDITION.

FOR this second edition the plates of the first have been carefully revised and corrected (except as indicated in the *errata* on the opposite page), and an entirely new chapter added (Chap. VIII, pp. 119–138), containing various notes and explanations, as also many examples for practice.

ITHACA, January, 1897.

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NOTES AND EXAMPLES IN MECHANICS.

CHAPTER I.

DEFINITIONS. PRINCIPLES. CENTRE OF GRAVITY.

1. Applied Mechanics is perhaps a more common term for the same thing than "Mechanics of Engineering." "Pure Mechanics" is another name for Analytical Mechanics, which deals with the subject entirely from a mathematical point of view.

2. Abstract Numbers.—In experimental investigations in which formulæ are to be deduced, it is best to throw experimental coefficients into the form of abstract numbers, if possible, for these are immediately comparable with those of another experimenter in the same field, if the latter follows the same plan, whether he uses the same units for space, force, and time, or not.

Thus: if the coefficient of friction be defined as the ratio of the friction [force] to the normal pressure [force] producing it, we obtain the same number for it in a definite experiment, whether we express our forces in pounds or in kilograms.

3. Forces.—One of the most important things to be acquired in dealing with the practical problems of this study is a proper conception of forces. We do not use the word *force* in any abstract general sense, nor in any popular sense, such as is instanced in the Note of § 15*c*, M. of E. It should always mean the pull, pressure, rub, attraction (or repulsion), of one body upon another, and always implies the existence of a simultaneous, equal, and opposite force exerted by that other body on the first body, i.e., the *reaction*; but this reaction will not come up for consideration in any problem *unless* this "first" body is under treatment as regards the forces acting on *it*. In most problems in Mechanics we have one or more definite rigid bodies under consideration, one at a time, in whose treatment we must form clear conceptions of the forces acting on it; and *these always emanate from other bodies.*

Hence in no case should we call anything a force unless we can conceive of it as capable of measurement by a spring-balance, and *are able to say from what other body it comes.*

For example, a body said to weigh 30 lbs. lies at rest on a smooth level table, which is the only body with which it is in contact. When considered by itself this body is acted on by only two other bodies in a manner which justifies the use of the word *force;* viz., the action of the earth upon it is a vertical downward attraction (force) of 30 lbs.; while the action of the table upon it is an upward pressure (force) of 30 lbs. (We here ignore the atmosphere whose pressures on the body are balanced in every direction.) But suppose the same body and the table with which it is in contact to be allowed to fall, from rest, in a vacuum. The two bodies, during the fall, remain apparently in as close contact as before; but now the upper body is under the action of only *one force*, viz., the downward attraction of the earth, 30 lbs.; and there is no pressure of the upper body against the table, and consequently no pressure of the table against the upper body.

As another instance, an iron rod rests horizontally on two level-faced supports, at its extremities, and bears a load of 60 lbs. in the middle. When this rod is considered "*free*," i.e., when those other bodies which act on it in a "*force*-able" way are supposed removed (their places being for present purposes taken by the respective forces with which they act on the first body), we find it to be under the action of four forces, viz.: a pressure on its middle, vertical and downward, of 60 lbs. from its load; the downward attraction of the earth on it, i.e., its own weight, say 10 lbs. (which is really distributed among all of its particles, but which, so far as the equilibrium, or state of rest or motion, of the body is concerned, is the same as if applied at the centre of gravity, viz., the middle of the rod); and the two upward pressures of the two supports against the ends of the rod, these being

35 lbs. each. If the nature of the investigation requires it, we may go on and consider one of the supports by itself, or "free"; in which case, whatever the actions of other bodies on it may be, that of the rod will be a downward force of 35 lbs., the equal and opposite of the 35 lbs. upward pressure of the support against the rod. These pressures of the two supports against the rod are usually called the "Reactions of the Supports."

As another instance: a ball of 10 lbs. weight hangs at rest by a cord attached to a support above. The cord is of course vertical. This ball is under the action of two forces, viz., a downward attraction of 10 lbs. emanating from the earth, and an upward pull of 10 lbs. emanating from the cord.

A portion of the above cord, taken in the part under tension, is under the action of two forces, thus: the part just above it exerts an upward pull of 10 lbs. upon it, and that below it exerts a downward pull of 10 lbs. upon it. (We here neglect the weight of the portion of cord considered as presumably very small.) In such a case the tension of the cord is said to be 10 lbs. (not 20 lbs.).

Further illustration. Fig. 1 shows a prismatic rod CB leaning against the smooth vertical side of a block. Both rest on a rough horizontal plane. The rod is under three forces, viz.: its weight G acting vertically downwards through its middle; the pressure of the wall against it, P (which, since the wall-surface is perfectly smooth, must be horizontal and points toward the right); and a third force, Q, the pressure of the floor against the rod. Since the rod and block are at rest, P and G intersecting at A, it must be that the floor is sufficiently rough to enable the pressure Q to deviate from the vertical (that is, from the normal to plane of floor) by as much as the angle ABV, *at least*; for, as will be proved later, if three forces act on a body and it remains at rest, the three lines of action must intersect in a common point.

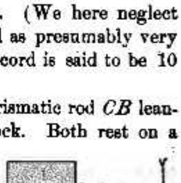

FIG. 1.

We next consider the block, or wall, by itself, and find it to