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Alexander Ziwil

THE
SCIENCE OF MECHANICS

A CRITICAL AND HISTORICAL ACCOUNT
OF ITS DEVELOPMENT

BY

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TRANSLATED FROM THE GERMAN

BY

THOMAS J. McCORMACK

SECOND REVISED AND ENLARGED EDITION

WITH 259 CUTS AND ILLUSTRATIONS

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CHICAGO

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Prof. Alex. B. T.
gt.
1-22-1923

TRANSLATOR'S PREFACE TO THE SECOND ENGLISH EDITION.

SINCE the appearance of the first edition of the present translation of Mach's *Mechanics*,* the views which Professor Mach has advanced on the philosophy of science have found wide and steadily increasing acceptance. Many fruitful and elucidative controversies have sprung from his discussions of the historical, logical, and psychological foundations of physical science, and in consideration of the great ideal success which his works have latterly met with in Continental Europe, the time seems ripe for a still wider dissemination of his views in English-speaking countries. The study of the history and theory of science is finding fuller and fuller recognition in our universities, and it is to be hoped that the present exemplary treatment of the simplest and most typical branch of physics will stimulate further progress in this direction.

The text of the present edition, which contains the extensive additions made by the author to the

* *Die Mechanik in ihrer Entwicklung historisch-kritisch dargestellt.* Von Dr. Ernst Mach, Professor an der Universität zu Wien. Mit 257 Abbildungen. First German edition, 1883. Fourth German edition, 1901. First edition of the English translation, Chicago, The Open Court Publishing Co., 1893.

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latest German editions, has been thoroughly revised by the translator. All errors, either of substance or typography, so far as they have come to the translator's notice, have been removed, and in many cases the phraseology has been altered. The sub-title of the work has, in compliance with certain criticisms, also been changed, to accord more with the wording of the original title and to bring out the idea that the work treats of the principles of mechanics predominantly under the aspect of their *development* (*Entwicklung*). To avoid confusion in the matter of references, the main title stands as in the first edition.

The author's additions, which are considerable, have been relegated to the Appendix. This course has been deemed preferable to that of incorporating them in the text, first, because the numerous references in other works to the pages of the first edition thus hold good for the present edition also, and secondly, because with few exceptions the additions are either supplementary in character, or in answer to criticisms. A list of the subjects treated in these additions is given in the Table of Contents, under the heading "Appendix" on page xix.

Special reference, however, must be made to the additions referring to Hertz's *Mechanics* (pp. 548–555), and to the history of the development of Professor Mach's own philosophical and scientific views, notably to his criticisms of the concepts of mass, inertia, absolute motion, etc., on pp. 542–547, 555–574, and 579

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-583. The remarks here made will be found highly elucidative, while the references given to the rich literature dealing with the history and philosophy of science will also be found helpful.

As for the rest, the text of the present edition of the translation is the same as that of the first. It has had the sanction of the author and the advantage of revision by Mr. C. S. Peirce, well known for his studies both of analytical mechanics and of the history and logic of physics. Mr. Peirce read the proofs of the first edition and rewrote Sec. 8 in the chapter on Units and Measures, where the original was inapplicable to the system commonly taught in this country.

THOMAS J. MCCORMACK.

LA SALLE, ILL., February, 1902.



AUTHOR'S PREFACE TO THE TRANSLATION.

Having read the proofs of the present translation of my work, *Die Mechanik in ihrer Entwicklung*, I can testify that the publishers have supplied an excellent, accurate, and faithful rendering of it, as their previous translations of essays of mine gave me every reason to expect. My thanks are due to all concerned, and especially to Mr. McCormack, whose intelligent care in the conduct of the translation has led to the discovery of many errors, heretofore overlooked. I may, thus, confidently hope, that the rise and growth of the ideas of the great inquirers, which it was my task to portray, will appear to my new public in distinct and sharp outlines.

E. MACH.

PRAGUE, April 8th, 1893.

PREFACE TO THE FIRST EDITION.

THE present volume is not a treatise upon the application of the principles of mechanics. Its aim is to clear up ideas, expose the real significance of the matter, and get rid of metaphysical obscurities. The little mathematics it contains is merely secondary to this purpose.

Mechanics will here be treated, not as a branch of mathematics, but as one of the physical sciences. If the reader's interest is in that side of the subject, if he is curious to know how the principles of mechanics have been ascertained, from what sources they take their origin, and how far they can be regarded as permanent acquisitions, he will find, I hope, in these pages some enlightenment. All this, the positive and physical essence of mechanics, which makes its chief and highest interest for a student of nature, is in existing treatises completely buried and concealed beneath a mass of technical considerations.

The gist and kernel of mechanical ideas has in almost every case grown up in the investigation of very simple and special cases of mechanical processes ; and the analysis of the history of the discussions concern-

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ing these cases must ever remain the method at once the most effective and the most natural for laying this gist and kernel bare. Indeed, it is not too much to say that it is the only way in which a real comprehension of the general upshot of mechanics is to be attained.

I have framed my exposition of the subject agreeably to these views. It is perhaps a little long, but, on the other hand, I trust that it is clear. I have not in every case been able to avoid the use of the abbreviated and precise terminology of mathematics. To do so would have been to sacrifice matter to form; for the language of everyday life has not yet grown to be sufficiently accurate for the purposes of so exact a science as mechanics.

The elucidations which I here offer are, in part, substantially contained in my treatise, *Die Geschichte und die Wurzel des Satzes von der Erhaltung der Arbeit* (Prague, Calve, 1872). At a later date nearly the same views were expressed by KIRCHHOFF (*Vorlesungen über mathematische Physik: Mechanik*, Leipsic, 1874) and by HELMHOLTZ (*Die Thatfachen in der Wahrnehmung*, Berlin, 1879), and have since become commonplace enough. Still the matter, as I conceive it, does not seem to have been exhausted, and I cannot deem my exposition to be at all superfluous.

In my fundamental conception of the nature of science as Economy of Thought,—a view which I indicated both in the treatise above cited and in my

pamphlet, *Die Gestalten der Flüssigkeit* (Prague, Calve, 1872), and which I somewhat more extensively developed in my academical memorial address, *Die ökonomische Natur der physikalischen Forschung* (Vienna, Gerold, 1882,—I no longer stand alone. I have been much gratified to find closely allied ideas developed, in an original manner, by Dr. R. AVENARIUS (*Philosophie als Denken der Welt, gemäss dem Princip des kleinsten Kraftmaasses*, Leipsic, Fues, 1876). Regard for the true endeavor of philosophy, that of guiding into one common stream the many rills of knowledge, will not be found wanting in my work, although it takes a determined stand against the encroachments of metaphysical methods.

The questions here dealt with have occupied me since my earliest youth, when my interest for them was powerfully stimulated by the beautiful introductions of LAGRANGE to the chapters of his *Analytic Mechanics*, as well as by the lucid and lively tract of JOLLY, *Principien der Mechanik* (Stuttgart, 1852). If DUEHRING's estimable work, *Kritische Geschichte der Principien der Mechanik* (Berlin, 1873), did not particularly influence me, it was that at the time of its appearance, my ideas had been not only substantially worked out, but actually published. Nevertheless, the reader will, at least on the destructive side, find many points of agreement between Dühring's criticisms and those here expressed.

The new apparatus for the illustration of the subject, here figured and described, were designed entirely