# PRINCIPLES

OF

# THE MECHANICS

OF

# MACHINERY AND ENGINEERING.


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FIRST AMERICAN EDITION.

## EDITED

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## IN TWO VOLUMES.

ILLUSTRATED WITH ONE THOUSAND ENGRAVINGS ON WOOD.

## VOL. I.

### THEORETICAL MECHANICS.


PHILADELPHIA:

LEA AND BLANCHARD.

1848.

PHILADELPHIA:

T. K. AND P. G. COLLINS, PRINTERS.

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# PREFACE BY THE AMERICAN EDITOR.

THE want of a good standard work on those branches of Mechanics which pertain to Machinery and Engineering, has long been felt as a deficiency in our means of instruction in the higher institutions, as well as in the office of the practical engineer. Any one who has had occasion to direct the study of young men preparing for the duties of the profession, must, in the course of his practice, have encountered the difficulty, on the one hand, of inducing students to extend their researches after the principles of their profession into the intricacies of the higher calculus, and, on the other hand, of contenting himself with the very limited discussion of principles, found in many works which have been hitherto employed to give the desired basis for professional knowledge. The difficulty has, of necessity, been met by the expedient of recommending detached parts of several distinct works.

The treatises on Natural Philosophy were a very inadequate substitute for a practical work on the Mechanics of Engineering. Many of the topics requisite to be handled in a work of this nature, are, in the books now in use, either wholly omitted, or so slightly passed over, as to be of little service beyond the general statement of certain laws, and perhaps a few illustrations, indifferently applied, and furnishing but feeble helps to the exact understanding of the laws applicable to the subject.

In presenting the claims of Prof. Weisbach's treatise to the consideration of Engineers and Machinists of the United States, we cannot do better than adopt the remarks of the English translator.

"From the well earned reputation of Professor Weisbach as a teacher and original investigator, from the interest which attaches itself, especially at the present moment, to all that pertains to Me-

chanics or Engineering, from the able manner in which he has treated both the theoretical and practical portion of his subject, and from the variety and abundance of examples which illustrate the principles and formulæ, it is presumed that a translation of his excellent work may not be unacceptable to the English reader. 'The Mechanics of Machinery and Engineering' has met with deserved favor in Germany, and is not unknown to many of the profession in our own country. The aim and objects of the undertaking are fully explained by the Author in his Preface; and it is hoped that the same end may be obtained here, by affording, through the medium of a translation, valuable aid to the acquirement of professional knowledge."

In the course of this volume, six great divisions of the science will be found to be embraced. Of these, the *pure mathematical science of motion*, including simple and compound, rectilinear and curvilinear motions, and the laws and expressions relating to the free descent of bodies, have, of course, claimed the first attention.

The *Physical Science of Motion* has next been treated; then the *division of forces*, and their *measure*,—the *density* and the *state of aggregation* of bodies have been duly presented. In the third section, the *statics of rigid bodies* claim a careful investigation, and are followed, in the fourth, by the *dynamics* of the same class of bodies; while, in the fifth, the *statics*, and in the sixth, the *dynamics of fluid bodies* are treated with marked ability; and in several parts with an originality and freshness which indicate that the author is here in his peculiar domain—the scene of his chosen labors, and that on which his energies, as an original inquirer, have been very successfully employed. In this branch of his subject, Prof. Weisbach has included the discussion of the mechanics of elastic as well as of non-elastic fluids. We are indebted to him for several new formulæ and valuable tables of constants.

As students of this work are, from the wide diffusion of French and German science, likely to meet, in other treatises, frequent references to French and German weights and measures, it has been deemed useful not only to present, as in the English edition, the annexed comparative table of weights and measures, but also to retain from the

*original* a few examples completely worked out as exercises in computation under the different systems. The same has been done in respect to temperatures measured by the Centigrade thermometer. The facility afforded by the decimal divisions of all the French weights and measures strongly recommend them both for scientific and practical purposes.

The additions of the American Editor are generally thrown into notes suitably designated, or, when embraced in the text, are usually enclosed in brackets. A number of new illustrations have been added, particularly such as relate to the principles of the "toggle joint," of rolling and dragging friction, of carriage wheels, and of floating docks. A table of co-efficients for the flow of water through wiers, the result of some recent experiments, not heretofore published, will be found in the sixth section.

It has been found necessary to make a very considerable number of corrections of the English copy, especially in the working of examples by the translator, where a departure from the original had been made, on account of a change of weights and measures. Should some few errors still have escaped notice, it will be no matter of surprise, and of the less importance, perhaps, since the principle of computation is in all cases pointed out, the steps severally indicated, and the general law, therefore, readily applied to each particular illustration.

A comparison with the original work in German has been made, and the great care exercised by the learned author in its preparation and publication has been rendered abundantly evident.

Justice to the artisans engaged in getting out the present edition requires us to say, that the illustrations here presented will not suffer in comparison with those of either the German or the English edition. In some instances they are decidedly superior to either.

PHILADELPHIA, *March*, 1848.

NOTE.—In regard to a matter of minor importance, that of the notation used in this work, a few words may be proper, in order to apprize the reader, in advance, that the use of the simple point (.) as the sign of multiplication has required the adoption of the comma

(,) to mark the decimal division of numbers. Should any departures from this application be observed, they will be such as are readily understood.

In using the Italian ($a$), and the Greek alpha ($\alpha$), the latter is most commonly applied to arcs and angles, and the former to lines or other quantities. This distinction, which is important to avoid confusion, and which is strictly observed in the original, has been sometimes lost sight of in the English edition.

# AUTHOR'S PREFACE.

In giving to the public the First Volume of my Elementary Treatise on Mechanics, for Engineers and Machinists, I feel some degree of diffidence. Although I am conscious that, in composing the book, I have proceeded with the greatest care and circumspection; I am, nevertheless, apprehensive that it cannot satisfy all, since the views, wishes and requirements of different individuals differ so widely. One reader may probably consider this or that chapter too long and too minutely treated, which another may find too short. Some will miss higher science in the treatment of certain subjects, which others would have wished to see treated in a still more popular manner. But many years of study, much experience in teaching, and continued observation, have led me to the method, according to which I have composed the present work, and I consider it the most appropriate for the intended purpose.

My chief aim in writing this work was the attainment of the greatest simplicity in enunciation and proof; and with this to give the demonstration of all problems, important in their practical application, by the lower mathematics only. If we consider the great variety of knowledge which the Engineer and Machinist have to acquire, who wish to do credit to their profession, we, their instructors, should make it our duty to render well-grounded study of science easy by simplicity of explanation, by the use of only the best known and easiest auxiliary sciences, and by eschewing everything that is unnecessary.

I have therefore avoided, in the present work, the use of the differential and integral calculus; for although there exist now more frequent opportunities, than formerly, for learning these methods, it is still unquestionable, that without constant practice, the readiness of using them is very soon lost; and that there are, consequently, many excellent practical men who have entirely forgotten how to apply them. Some popular authors give the results of the more difficult problems without proofs. I cannot approve of this, and have pre-

ferred to give the proofs of practically important problems in an elementary way, although this may sometimes appear rather long and tedious. There are, therefore, but few formulæ in the work unaccompanied by their derivation. A general acquaintance with some doctrines of natural philosophy, but especially an intimate knowledge of pure elementary mathematics, are of course necessary for the understanding of the present work.

I have taken especial pains to preserve the right medium between *generalizing* and *individualizing;* for, although I am fully aware of the advantages of generalization, I must still adhere to the opinion, that in an elementary work, too much generalizing is to be avoided. Simple cases are, in practice, of more frequent occurrence than complicated. It is also undeniable, that in treating a general case, the knowledge which might be gained by the treatment of a specific case, is frequently lost, and that it is not unfrequently easier to deduce the compound from the simple, than to eliminate the special from the generale

The "Mechanics of Engineering and Machinery" must not be mistaken for a work on the construction of machines, but it is to be considered merely as an introduction to or preparatory science for this. This Treatise of Mechanics is to stand in the same relation to the construction of machines, as descriptive geometry stands to the drawing of machines. After mechanics and descriptive geometry have been learned, the instructions on the construction and the drawing of machines may with advantage be united in one course.

The propriety of dividing the Mechanics of Engineering into a theoretical and practical part, may perhaps be doubted. If it be borne in mind, that this work is to furnish instructions on all mechanical relations, in architecture and the science of machines, the utility, or rather necessity of this division must be apparent. In order to form a complete opinion of a building or machine, the most various doctrines of mechanics (*i. e.* the doctrines of friction, strength of materials, inertia, impact, efflux, &c.), must be taken into consideration; the material for the study of the mechanics of a building or machine must, therefore, be collected from all parts of mechanics. Now, as it is much more useful practically to be able to study the doctrines relative to every individual machine in connection, than to have to collect them from all departments of mechanical science, the utility of the adopted division seems to be beyond all doubt.

Having practical application always in view, I have endeavored to illustrate each doctrine, as much as possible, with appropriate

examples, taken from practice; and I can truly assert, that this book excels most works of a similar nature, in the great number and appropriate choice of worked out examples. The large number of carefully executed figures will, no doubt, likewise assist the attainment of the above-mentioned object; and I cannot omit here to express how greatly satisfied I feel with the manner in which the publishers have performed their part in the getting up of the book.

Finally, it is necessary to point out to the reader of the work, that he will find much that is new and peculiar to the author. Passing over smaller matters, which occur in almost every chapter, I will mention only the following more comprehensive subjects. A general and easy method of determining the centre of gravity of plane surfaces and even-sided polyhedra, will be found in the paragraphs, 107, 112, and 113; an approximate formula for the catenary in the paragraphs 147 and 148; supplements to the theory of the friction of axes in the paragraphs 167, 168, 169, 172, and 173. The doctrine of impact especially has received essential additions by the paragraphs 262 and 263, since the impact of imperfectly elastic bodies has been hitherto insufficiently treated; and the case, where a perfectly elastic body comes in contact with a partially elastic body, has been passed over entirely. The largest number of additions, and some entirely new laws will be found in the hydraulics, the author having made this branch of the sciences his particular study during a number of years. The laws of the incomplete contraction of the fluid vein, discovered by the author, appear here for the first time in a course of mechanics. The chief results of the author's experiments on the flow of water through slides, cocks, clacks and valves, are likewise given, as well as his principal observations made during his latest experiments on the flow of water through prolonged oblique tubes, and through angular, curved, and long straight tubes, though he has not yet been able to publish the third number of his "Untersuchungen im Gebiete der Mechanik und Hydraulik," which is to contain the results of these experiments. The chapters on flowing water and the gauging and impulse of water have likewise received additional matter from the author.

But now, after completion of the first volume, I cannot refrain from wishing that several subjects had been treated in a different manner, although I have not been able to discover any essential errors or imperfections in it. Should the reader here and there find omissions, I must refer him to the second volume, which will contain supplements,

most of which have been intentionally reserved for that volume, as has been mentioned in several passages of that now published.

It will give me great satisfaction and pleasure, if the purpose which I had in view in writing this work has been attained in some measure. I wished to supply the practical man with useful advice, the instructor in mechanics with a guide for teaching, and the young engineer and machinist with a welcome auxiliary for the acquirement of the science of mechanics.

JULIUS WEISBACH.

FREIBERG, *March*, 1846.

# COMPARATIVE TABLES OF ENGLISH, FRENCH, AND GERMAN MEASURES AND WEIGHTS.

### I. Measures of length.

| English (and Russian) foot. | French metre. | Paris foot. | Prussian, Danish, and Rhenish foot. |
|---|---|---|---|
| 1 | .3047945 | .9382928 | .9711361 |
| 3.280899 | 1 | 3.078444 | 3.186199 |
| 1.065765 | .3248394 | 1 | 1.035003 |
| 1.029722 | .3138535 | 0.9661806 | 1 |

### II. Square measure.

| Square foot. | Sq. metre. | Square foot. | Square foot. |
|---|---|---|---|
| 1 | .09289969 | 0.8803934 | 0.9431053 |
| 10.76430 | 1 | 9.476817 | 10.15187 |
| 1.135856 | .1055207 | 1 | 1.071232 |
| 1.060327 | .09850405 | 0.9335049 | 1 |

### III. Cubic measure.

| Cubic foot. | Cubic metre. | Cubic foot. | Cubic foot. |
|---|---|---|---|
| 1 | .02831531 | 0.8260668 | .9158836 |
| 35.31658 | 1 | 29.17385 | 32.34587 |
| 1.210556 | .03427727 | 1 | 1.108728 |
| 1.091842 | 0.9019342 | .03091584 | 1 |

### IV. Measures of capacity.

| English gallon, =277.27384 cubic inches. | French litre, =.001 cubic metre. | Prussian quart, =64 cubic inches. |
|---|---|---|
| 1 | 4.543458 | 3.967977 |
| .2200967 | 1 | 0.8733386 |
| .2520176 | 1.145031 | 1 |

| Bushel, =8 gallons. | Hectolitre, =100 litres. | Scheffiel, =3072 cubic inches. |
|---|---|---|
| 1 | 0.3634767 | .6613296 |
| 2.751208 | 1 | 1.819455 |
| 1.512105 | 0.5496150 | 1 |

### V. Weights.

| English pound, avoirdupois. | French. | | Prussian, Hanoverian, Brunswick, and Hessian pound. |
|---|---|---|---|
| | Kilogram. | Livre, poids de marc. | |
| 1 | .4535976 | .9266439 | .9698245 |
| 2.204597 | 1 | 2.042879 | 2.138072 |
| 1.079163 | .4895058 | 1 | 1.046599 |
| 1.031114 | .4677110 | .9554758 | 1 |

| Hundred weight. =112 lbs. avd. | Quintal metrique. =100 kilo. | Quintal, =100 livres (old measure.) | Centner, =110 lbs. |
|---|---|---|---|
| 1 | 0.5080293 | 1.037841 | 0.9874577 |
| 1.968390 | 1 | 2.042877 | 1.943702 |
| 0.9635386 | 0.4095058 | 1 | 0.9514536 |
| 1.012702 | 0.5144821 | 1.051023 | 1 |

L. G.

The United States standard gallon has a capacity of 231 cubic inches, and contains 8.3388822 avoirdupois pounds, or 58372.1754 Troy grains of distilled water at 39°.83 Fah., the barometer being at 30 inches. The U. S. standard bushel contains 2150.42 cubic inches, and 77.627413 pounds avoirdupois of distilled water at 39°.83 Fah.—Am. Ed.

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