experiment or by reference to a posteriori information. Space being obtained by abstraction, is unique, and has definite properties, and requires no *axioms* for its development. The theory of parallels is only a side issue of the implications of the straight line. The author leads the reader to expect the conclusion that Euclid alone is valid, yet he says later (page 121), "The result of our argument is quite conservative. It reestablishes the apriority of mathematical space, yet in doing so it justifies the method of metaphysicians in their constructions of the several non-euclidean systems."

There is much vagueness and apparent contradiction in the book. The abstraction process, except in so far as it is purely intuitional, would seem, if definite at all, to be nothing more than an arbitrary process, and hence equivalent to a set of axioms. The author is not concerned with any question of betweenness, or of continuity, except as involved in notions of homogeneity, evenness, his interest being almost entirely in the parallel axiom and its implications.

The book concludes with an epilogue in which the analogy between mathematics and religion is discussed, although the precise analogy is not quite clear.

F. W. OWENS.

Mechanics. By JOHN COX. Cambridge University Press (Cambridge Physical Series), 1904. Demy 8vo. xiv + 332 pp.

THIS book ought to have a far reaching influence on the teaching of elementary mechanics. It contains really good illustrative examples, concrete, practical, and instructive, and at the same time, gives clear and accurate statements of the fundamental principles. It is not overloaded with theory more general than ordinary applications require. Further, principles are expressed in words rather than by formulas. In simple examples it is clumsy to use a general formula, in complicated examples verbal expression often clears the view, in all examples the mere substitution of numerical values in a formula is poor practice.

Two paragraphs from the author's preface are worth quoting. "Some years ago I stumbled on the first German edition of Professor Mach's Die Mechanik in ihrer Entwicklung. . . . Since then my teaching has been based more and more on the lines laid down by Mach, and as I have found it impossible to induce ordinary students to read the original even when translated, I recurred to the idea of writing a text book which should yet be based on Mach's method."

"Until Mechanics is clad in its historical flesh and blood, it will remain the dull and tiresome subject that has convinced so many generations of students that an abysmal gulf separates theory from practice."

The book is divided into four sections: historical, mathematical formulation, various applications, rigid dynamics.

The first section deals successively with Archimedes' treatment of the theory of the lever in the third century B. C., and applications including centers of gravity and the balance; Stevin's solution of the problem of the inclined plane in the sixteenth century and extensions to the parallelogram of forces and virtual work; Galileo's foundations for dynamics, their application to uniform motion by Huyghens, and Newton's deductions from the theory of universal gravitation, all in the seventeenth century.

The second section begins with a chapter on kinematics, followed by the laws of motion and their verification by Atwood's machine, energy, the usual treatment of the equilibrium of forces in a plane, and friction.

The various applications in the third section include brachistochrones, projectiles, simple harmonic motions, with Fresnel's rule for compounding them, the simple pendulum, an outline of Newton's Principia, and impact.

The elementary theory of rigid dynamics contains chapters on Huyghens's treatment of the compound pendulum, D'Alembert's principle, moments of inertia and their experimental verification, determination of gravity by Kater's pendulum and the Cavendish experiment.

It is by following the historical order of development, by bringing the reader into close contact with original masterpieces, and by the concrete illustration of principles in practice that the author has produced a book so valuable that any criticism seems ungenerous.

But the book is the beginning of a new era, not the last word in an old one. There are a few errors in the answers to examples, but this is no disadvantage for classwork. A freer use of the concepts and notation of the calculus would be more in accord with present ideas, and amongst other things, would avoid the unsatisfactory treatment of motion down a smooth curve as the limit of motion down a series of inclined planes without any consideration of the impacts involved.

In the section devoted to mathematical formulation no mention is made of centers of gravity or of the vector law of addition. Varignon's theorem of moments should have a proof more modern than his own geometrical one. The treatment of forces in one plane acting on a rigid body would be more satisfying if the logical steps were made clearer. The following definition of equilibrium is tacitly assumed: A system of forces in one plane acting on a rigid body is in equilibrium if the sum of their moments about every point in that plane is zero.

Lastly, how about the definitions of mass and force? Of all sources of error these are the most persistent. There are two logical systems, to be found respectively in Mach's Science of Mechanics and Maxwell's Matter and Motion. In the former, which is purely dynamical, first mass and then force are defined by combining Newton's second and third laws. "All those bodies are of equal mass, which, mutually acting on each other, produce in each other equal and opposite accelerations." In the latter, equal forces are defined by their statical effect and Newton's first law and then Newton's second law furnishes a definition of mass.

"If a body moves with constant velocity in a straight line, the external forces, if any, which act upon it balance each other, or are in equilibrium." (Article 42.)

"We shall assume that it is possible to cause the force with which one body acts on another to be of the same intensity on different occasions. . . . We know that a thread of caoutchouc when stretched beyond a certain length exerts a tension which increases the more the thread is elongated. . . . When the same thread is drawn out to the same length it will, if its properties remain constant, exert the same tension." (Article 45.)

"Hence any two bodies are of equal mass if equal forces applied to these bodies produce, in equal times, equal changes of velocity. This is the only definition of equal masses which can be admitted in dynamics, and it is applicable to all material bodies, whatever they may be made of." (Article 46.)

The author is surely right in throwing over Mach's definitions and adopting those of Maxwell. In Matter and Motion, however, there are passages which tend to obscure the scheme outlined in the three extracts quoted above, and in the author's article dealing with mass and force (pages 116–118) there is a corresponding haziness of outline. It is distinctly unfortunate that the only definition of force given in the book is that of Newton, "Force is anything which changes or tends to change a body's state of rest or of uniform motion in a straight line." That this definition almost immediately precedes Maxwell's definition of equal masses quoted above, makes the omission still more serious. Still, the work should rank as the most important contribution of late years to the teaching of elementary mechanics.

W. H. JACKSON.

Theorie der Elektrizität. Von M. ABRAHAM. Zweiter Band: *Elektromagnetische Theorie der Strahlung.* Zweite Auflage. Leipzig, Teubner, 1908. xii + 404 pp.

THE earlier edition of Abraham's Theory of Electricity was reviewed in these pages,* and no very extensive mention of the present edition seems needed. Although the number of pages in 1908 remain identical with that of 1905, and neither the titles nor the numbers of the sections are disturbed until the last quarter of the book, there have been introduced into the new edition some considerable and important alterations and improvements aimed to keep the work up to date. A saving here and there of about 18 pages up to the point where the author discusses phenomena in moving bodies and a thorough rewriting of the theory of moving bodies enables him to give to this subject the careful and critical discussion which its rapid advance and numerous controversies of the last few years necessitate. As points of especial interest may be mentioned the presentation of the equations of Lorentz, Cohn, and Minkowski with a discussion of their individual characteristics, the development of the dynamics of the Hohlraum, the treatment of local time, and the investigation of the principle of relativity. These matters are all still under critical discussion in the scientific world and are perhaps likely to remain in the spotlight for some time. The account here given by Abraham seems particularly valuable in that it enables the reader to get a good knowledge of the subjects from a single author and a single reference.

The principle of relativity is an interesting hypothesis and

* BULLETIN, 2d ser., volume 14 (1908), pp. 230–237.