capillary electrometer in consequence of the electrical disturbance in the organ which is 'the organ shock.' A number of these records were exhibited; they showed the time relations, mode of commencement and manner of subsidence of the shock, and demonstrated its similarity to the electrical changes known to exist in nervous tissue during the passage of a nervous impulse. A remarkable feature of the organ shock as distinct from the phenomena of nerve was then brought forward. The shock even when evoked by a single stimulus was shown to be rarely if ever a single one. Each effect consists of a rhythmical series of electrical changes occurring one after another in a perfectly regular manner at intervals of $\frac{1}{100}''$ to $\frac{1}{300}''$, the rate depending upon the temperature. By special experiments it was shown that this rhythmical series is due to self-excitation, each change producing an electrical current of sufficient intensity to excite the nerves of the tissue in which it was generated. It follows that only the initial member of the series need be evoked by nervous impulses descending the nerves, since the others must then ensue. The potency of the organ as a weapon to be wielded by the fish is thus enormously increased by its resemblance to a self-loading and self-discharging automatic gun. The total electromotive-force of the whole organ in a fish only eight inches long can reach the surprising maximum of 200 volts, at any rate in the case of the initial shock. The attainment of this maximum is due to the simultaneous development of perfectly similar electromotive changes in each of the two million discs of which the organ is composed. In a single disc the maximal electromotive force only amounts to from .04 to .05 volt, and since in a small nerve an electrical change of .03 to .04 volt has been observed, the large total effect is not due to any extraordinarily intense electrical disturbance in each tissue element, but to the tissue elements being so arranged that the effect in one augments those simultaneously produced in its neighbors.

Finally, the remarkable characters of the nervous connections of the organ were described. Each lateral half of the organ, although it has a million plates receiving nerve branches, is innervated by one single nerve fiber and this is the offshoot of a single giant nerve-cell situated at the cephalic end of the spinal cord. The structure of this nerve-cell was displayed by means of microscopic sections and by wax models made by G. Mann, of Oxford. As regards the nervous impulses which the fish can discharge through this nerve-cell, experimental results were described which show that the fish is incapable of sending a second nervous impulse after a preceding one until a period of $\frac{1}{10}$ second has elapsed, and that this interval is rapidly lengthened by fatigue to as much as several seconds. The inability of the central nervous system to repeat the activity of the organ obviously presents disadvantages to the use of the shock as a weapon for attack or defence, but such disadvantage is more than counterbalanced by the property of the organ alluded to in the earlier part of the lecture, viz., that of self-excitation, since a whole series of shocks continue to occur automatically in rapid succession provided that an initial one has been started by the arrival of the organ of a nervous impulse sent out from the central nerve-cell.

FRANCIS GOTCH.

## SCIENTIFIC BOOKS.

*The Elements of Alternating Currents.* By W. S. FRANKLIN and J. WILLIAMSON. New York, The Macmillan Company. 212 pages.

This book gives an exposition, or rather introduction into the engineering methods of investigation, that is, those methods which are used in practice to investigate the phenomena taking place in alternating circuits, and to design alternating apparatus.

The contents of the book are:

Chapters I. to IV., General Principles of Alternating Waves and Measurements.

Chapters V. to VII., Inductive Circuits, Parallel and Series Connection.

Chapters VIII. to XV., Alternators, Transformers, Synchronous Motors, Converters, Induction Motors, Transmission Lines.

The book is based on college experience and intended as a text-book for colleges, and fulfills this object admirably, better than any other book on these subjects that I know, not only by what it gives but also by what it omits. It does not give design of alternating apparatus except in a few isolated cases, which would preferably have been omitted also. The designing data and methods in the present state of the electrical industry form one of the most valuable assets of a few large manufacturing companies, and thus are practically inaccessible to the public, so that any book claiming to teach design of alternating apparatus can immediately be recognized as an intentional or unintentional fraud.

In electrical engineering, as in most branches of science, two methods of investigation exist. The *differential method* compounds the equations of the phenomena taking place in the time differential. It is the only exact method, and the method which has given broad results of universal importance in the hands of men such as Maxwell and Heavyside, but in the hands of anybody but a mathematical genius, this method is absolutely barren of results. In engineering practice to integrate the differential equations, such assumptions have to be made that ultimately the result, derived by excessive labor, applies to phantom apparatus only, as a hysteresis-less transformer, or an induction motor without self-induction, or any such monster.

In the *integral method*, the time differential and to a large extent, the time as variable has altogether disappeared, the alternating wave is represented by its quadratic mean and its phase, the E.M.F of self-induction finds its expression in a constant ohmic reactance, and even the hysteretic loop has disappeared and is represented by an angle of advance of the phase of magneto-motive force with regard to the magnetic flux.

This method is naturally an approximation only, and after the problem has been solved the results have to be discussed regarding their accuracy, and corrections applied to allow for secondary effects, as higher harmonics, etc., just as in astronomy the preliminary orbit of a comet has to be corrected for the disturbances caused by the planets.

But the integral method is the only method which is of practical utility, whether as graphical or trigometrical, or symbolic treatment in complex quantities.

Unfortunately in our colleges, usually, too much preponderance is still given to the differential method, starting from Green's theorem and leading into the nowhere, and further time wasted by spreading misinformation in the attempt to teach apparatus design, although, fortunately, a reaction is setting in now by replacing the teaching of apparatus design by that of a thorough understanding and study of the actions and internal reactions of the apparatus, and differential methods by engineering methods.

I believe, however, that these differential methods might better be dropped altogether from the curriculum of our colleges, and the time saved thereby distributed between the teaching of engineering methods, for which the above discussed book forms a very suitable text-book, and is especially intended, and differential calculus pure and simple, endeavoring in the latter to give the student a thorough understanding and intuition into the fundamental principles rather than to load his memory with a lot of useless, because immediately forgotten, formalism. There appears to me no branch of science more tedious than mathematical physics. Mathematically, it has neither the interest nor the elegance of pure mathematics, and physically, it is, with very few exceptions, barren of results.

CHAS. P. STEINMETZ.

*Kinematics of Machinery.* By JOHN H. BARR, M.S., M.M.E., Professor of Machine Design, in Sibley College, Cornell University. New York, Wiley & Sons. London, Chapman & Hall. 1899. 8vo., pp. v + 247, 213 illustrations, cloth. $2.50.