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THE ELEMENTS OF PHYSICS.

The Elements of Physics. By Edward L. Nichols and William S. Franklin. Vol. i. Mechanics and Heat. Pp. x + 228. Vol. ii. Electricity and Magnetism. Pp. ix + 272. Vol. iii. Light and Sound. Pp. vii. + 201. (New York: The Macmillan Company. London: Macmillan and Co., Ltd., 1896.)

THE title and contents of such a work as that before us open up many questions regarding physical theory and its presentment, on which every teacher must hold more or less strong views resulting from his training and experience. Hence, in reviewing it, the temptation to discuss particular points rather at length is almost too powerful to be resisted, and perhaps need not always be overcome. If then, in what follows, there is any noticeable tendency of this kind, it is not to be supposed that the pronouncement of the authors is necessarily objected to; but that some passage or other has suggested what may appear to be rather a digression.

The authors have endeavoured to give a short and clear account of the various quantities in the subjects of Mechanics, Heat, Electricity, Optics, and Acoustics, which are capable of exact measurement. Of course, within the limits of space assigned, a full theoretical discussion is impossible; but each concept is carefully explained, and an indication is given of how its numerical magnitude can be determined. The work is in our opinion a thoroughly sound and satisfactory introduction to the science of physical measurements.

Volume i. begins with a chapter on Length, Time, and Mass. It includes an account of such length-measuring instruments as the scale and vernier, cathetometer, dividing engine, and spherometer, and of instruments for weighing and the measurement of time. These discussions are merely in skeleton, and must be supplemented as regards both the theory and the use of the instruments by reference to more exhaustive special treatises.

With regard to the measurement of time, variation in the amplitude of vibration of a clock-pendulum ought, as the authors say, to be avoided as far as possible by making the gear and escapement of fine workmanship, and no sensible alteration of the rate of a clock ought to be allowed to arise from such a cause. Since, however, the word "pendulum," as used by the authors, appears to include the balance of a pocket chronometer or watch, it would have been well to point out here that, in such a case, large variations of amplitude with changes of position of the chronometer cannot be avoided, and to mention the interesting fact that practical equality of period is, in such circumstances, secured by carefully adjusting the balance-spring to the exact length for which the long and short vibrations are most nearly isochronous. We may refer, in connection with this very important subject, to a valuable, though apparently little known, memoir by M. Phillips in *Liouville's Journal*, Sér. ii., Tome v. (1860), in which the Breguet form of balance-spring, with

its peculiarly curved over-coil, now generally adopted in compensated chronometers, is arrived at as a result of mathematical calculation.

The chapter on Physical Quantity contains a very short account of the Dimensions of Derived Units. The exact meaning and force of a dimensional equation are of great importance, and a page or two of additional space might with advantage have been devoted to this subject, at the expense, if need were, of the explanation of vector-products which comes immediately after, and which, so far as we have observed, is not called into active service subsequently in the book.

The authors rightly devote a little space to making clear exactly what is meant by the equality of action and reaction asserted in the third law of motion. It is curious that the most essential point is not more emphasised in elementary text-books of dynamics, namely, that the action and reaction, which are equal and opposite, and which act across the same cross-section of a wire or rod, or across the surface of contact of two links of a chain, and which the ordinary learner often thinks ought to cancel one another, are opposite forces *acting on different portions of matter*, and therefore do not annul one another, unless the rate of change of momentum of a system including both portions of matter is under consideration.

It is remarkable that the paradoxer who insists on making the mistake here indicated, and supports his views with so much nonsensical rigmarole, mixed up with wild talk about conspiracies of mathematicians to defend the views of Newton, never commits a similar error in financial matters! He does not consider the handing over of a sum of money by one person—himself, for example—as cancelled by its receipt by another person. Yet the two aspects of this transaction (like the forces which are the two aspects of a stress) are equal and opposite; but they affect different persons, and he sees clearly enough that one cannot be regarded as annulling the other, unless the question is as to the total sum of money possessed by the two persons concerned.

We may remark that it does not seem clearly brought out in connection with the experiments of Galilei, mentioned on p. 36, that what was proved by his famous experiments on bodies let fall from the top of the leaning tower of Pisa to the pavement beneath, and also by Newton's pendulum experiments, was the proportionality of the gravities of different bodies to their inertias. Hence the experiments show that when the masses of bodies are measured by their inertias, the results are equivalent to those obtained by the process of weighing.

In this chapter the authors call a velocity of one centimetre per second a "kin." There is undoubtedly an advantage in having names for the units of quantities which are apt to be confounded; but velocity and acceleration are both so fundamental conceptions as to make it imperative on the student to completely master their meaning and the manner in which they involve the fundamental units, if he wishes to make any progress at all; and we question if there is any real want of names for their units.

Equation (48) on p. 50, expresses a result in simple harmonic motion which is one of the few formulæ in

physics it is desirable to carry in the memory for instant use. It would be more portable if made explicitly kinematical by being reduced to the form

$$\frac{\text{acceleration}}{\text{displacement}} = \frac{4\pi^2}{T^2},$$

where, on the left, numerical values without regard to sign are understood. The introduction of the mass m of the vibrating particle, together with a quantity α , which is the product of m by the positive numerical value of the acceleration, seems an unnecessary complication.

The authors give in Chapter vi. an excellent elementary account of stress and strain. Everything is clearly and concisely stated, and a student seeking an accurate quantitative outline of the subject as a starting-point for a more complete study of experimental elasticity could hardly find anything more satisfactory.

We note in this chapter the use of the form "elotropy" for "eolotropy" (or, better, "æolotropy") to denote difference of elastic quality in different directions in a body. It seems hardly allowable to adopt this spelling in view of the derivation of the first part of the word from *αἰόλος*, meaning *quick-moving*, *changeable*, *variegated*.

It is of considerable experimental importance to point out that what the authors call the constant of torsion of a wire (that is, the torsional rigidity) is calculated on the assumption of perfect circularity of cross-section, and further involves the fourth power of the radius of the wire; so that it is hardly possible to draw from oscillation experiments exact conclusions as to the value of the rigidity-modulus of the material.

The definition of perfection of elasticity, on p. 102, seems hardly guarded enough. A body may, after the removal of stress, return to precisely its former configuration, so far as that can be tested at least, and yet be subject to imperfections of elasticity. Let the body be subjected to increasing stress, and let the successive configurations be noted; then let the stress be gradually altered back again to the former value, and the configurations in returning be again noted. If the configuration corresponding to a given value of the stress be the same during the removal of the stress as during its imposition, the body is perfectly elastic, but not otherwise. If the configurations and stresses be represented graphically, the curves for the transition from initial to final stress may not coincide with that for return from final to initial stress, and energy will be dissipated (in consequence of imperfection of elasticity), the amount of which can be estimated from the area enclosed between the two curves.

The next chapter (vii.) deals with Hydro-Mechanics, a subject the extent of which must have been very embarrassing to the authors, considering their plan, and the amount of space at their disposal. On the whole, they have given a fair account of leading principles, and especially of those of capillarity and viscosity; and we have in these all the merits of treatment that mark the rest of the work.

In the remarks in this chapter on the experimental verification of Boyle's law (Mariotte's or Boyle's law the authors call it!), there is no reference to what constitutes the real divergence of gases, such as nitrogen, oxygen and hydrogen, from fulfilment of this law. In fact, it is

stated that for a gas the "loss of volume is greater than would be expected from Mariotte's law, the divergence from inverse proportionality increasing as we near the point of condensation." But, as no doubt the authors are fully aware, deviations from fulfilment of Boyle's law are not confined to gases which are in "an intermediate condition preparatory to liquefaction," but are found also in true gases—gases, that is to say, which are far above their critical temperatures. The researches of Regnault, and the later and much more extended investigations of Amagat, which have given us most complete and interesting information as to how far "true gases" conform to Boyle's law, are of great importance from the point of view of kinetic theory, and should surely have been noticed here.

The account given in Art. 192, p. 136, of efflux of liquid from an orifice in a vessel, seems to require amendment, which should also be extended to Art. 193. As a matter of fact, the pressures at the outside of the jet and at the free surface are practically the same, so that $p - p_1$, instead of being equal to ρdg , is really zero. Also, though this is a small matter, it would seem better to use ρ than d to denote density; as expressions like dv^2 , dg , are instinctively associated with other meanings than those intended.

Passing now to the part of the book which treats of Heat, we are glad to see so excellent an account of the subject of temperature. It is short, and seems to be correct; which is more than can be said of nine out of ten of the discussions in text-books on this very important subject. Of the fact that thermometers made with different kinds of glass, and graduated with absolute accuracy, will agree at the temperatures of reference, 0°C . and 100°C ., and will agree nowhere else, the majority of text-book writers seem to be in blissful ignorance. Nothing is more confusing than the customary proceeding (much followed by a certain class of writers on thermodynamics!) of defining temperature on a mercury-in-glass thermometer, sometimes with ignorance of the expansion of the vessel, sometimes not; but always with the further erroneous statement that the increase of pressure of a gas kept at constant volume is the same for each degree of rise of temperature on this scale, a "fact" which is supposed to express the law of Gay-Lussac. It does not occur to such writers that, if Gay-Lussac's law were to thus hold for one thermometer, it could not hold for other thermometers made with different kinds of glass, and therefore having different scales. And, unhappily for those who define their scale of temperature with regard to the absolute expansion of mercury, with or without nonsense about mercury being "chosen on account of its uniform expansion," the divergence of the air-thermometer from such a standard is much greater than from a thermometer constructed with ordinary glass.

The vicious circle thus introduced into the definition of the standard scale of temperature, and the failure to regard the air-thermometer scale and the absolute thermodynamic scale of temperature as each derived from its own independent definition, is responsible for much of the prevalent haziness in the application of the fundamental principles of heat and thermodynamics.

These mistakes are avoided in the book before us ; but we cannot help thinking that the part of the book which deals with thermodynamics would have been improved by a somewhat different order of treatment. The first real step in thermodynamics should always be a discussion of Carnot's heat-engine and Thomson's definition of absolute temperature. Then, all about the behaviour of gases, and the deviation of temperature as defined on the air-thermometer from absolute thermodynamic temperature, could have been told, we think, much more effectively. As it is, Joule and Thomson's experiments, which we are informed were made for the purpose of deciding whether there is any sensible attraction between the particles of a gas, are mentioned only once in the book, and that long before the scale of absolute temperature is referred to. The most important part of the significance of this investigation is really lost unless its bearing on the realisation of absolute temperature is fully pointed out. We may have unduly emphasised this omission ; but we are sorry a book, so generally good as this is, should have in any degree missed an opportunity of insisting on absolute temperature and all that thereto relates, as the first and fundamental thing, we had almost said the only thing, in thermodynamics.

The second and third volumes of Messrs. Nichols and Franklin's book, which deals with Magnetism and Electricity, we have but little space left to deal with. But we may say at the outset that, good as the first volume seems to us to be, these seem quite up to the same level.

In vol. ii. a short and satisfactory account of Galvanometry is given under the heading of Electrolysis and Batteries. The laws of electrolysis are stated, and some space is devoted to a discussion of the Energy Theory of the Voltaic Cell, though not more than or even quite as much as the importance of the subject deserves. In the sketch of the thermodynamics of the voltaic cell the phrase, "sweeping processes performed by the current," strikes one as quaint, to say the least. The "sweeping process" is not performed by the current at all, but by Messrs. Nichols and Franklin when they draw an indicator diagram to represent a certain part of the work done by the current.

The book is brought up to date by an account of the kathode discharge within a Crookes' tube, and of Röntgen's discovery. This chapter contains, besides, a very brief account of the discoveries of Hertz.

Practical Applications are dealt with in a chapter mainly devoted to Electric Signalling. The usual telegraphic devices are described ; but none of the vexed questions on this subject are gone into. The authors, however, do say that the so-called KR law holds for telephonic signalling as well as for submarine telegraphy, which is, to say the least, a rather inadequate statement.

A chapter on Mechanical Conceptions of Electricity and Magnetism completes the second volume. The idea adopted is that the ether in a magnetic field has a cellular structure, and that these cells have a rotational motion about axes parallel to the direction of the field at each point, while the lines of electric force are marked by displacement of these ether-cells—the positive in one direction, the negative in the opposite. There are, of course, serious difficulties in this mode of regarding what

takes place ; so much so, that there seems now rather a consensus of opinion in favour of the view that the direction of magnetic force is that of flow of the ether regarded as a perfect fluid. Such questions, however, the authors, probably from want of space, do not discuss.

Volume iii. begins with a statement of the distinction between light and sound as cases of wave-motion, and a comparison of the methods of determining their velocities of propagation. Then follows an account of wave-motion with the usual theorems on composition of vibrations, constructions for wave-fronts of reflected and refracted waves, Huyghens' zones, &c. The succeeding chapters deal with the theory of mirrors and lenses, treated, as they always ought to be in a physical book, by means of considerations of wave-propagation and the principle of equal optical distances. The old rule, convenient for use in the approximate fashioning of glass lenses, might have been noticed at p. 47, that the radius of the opening of a convex lens is nearly (for index of refraction 1.5) a mean proportional between the focal length of the lens and its thickness.

The chapter on Dispersion (prismatic) strikes us as capable of considerable expansion. The conditions for obtaining a pure spectrum do not seem to be stated, except in so far as they are given more or less implicitly in connection with the spectroscope. In preparation for this an elementary account of primary and secondary focal lines might be added to the chapter on lenses, and the reason for placing the prisms of a spectroscope in the position for minimum deviation explicitly brought out.

The account of double refraction we find unexpectedly short. Refraction in uniaxal crystals is alone treated, Huyghens' construction is given for the single case of Iceland-spar, and there is no notice of the other typical case, that of quartz.

But the most serious omission in this volume, perhaps in the book, is that of any adequate discussion of magneto-optic rotation. Article 754 is devoted to "Rotation of the plane of polarization ; the saccharimeter," and Art. 755 (rather more than half a page) deals with magneto-optic rotation. The latter subject is not discussed in vol. ii., and we had expected to find in vol. iii. an account of phenomena, of the very important absolute determinations of Verdet's and other constants that have been made, and of the applications of the knowledge so obtained in magnetic research. As it is, six lines are given to rotation of the plane of polarised light in bisulphide of carbon, and the remainder to a photo-chronograph, which, though ingenious and valuable, hardly in the circumstances should have had so relatively large a part of the available space devoted to it.

In our account of this work we have referred to a number of points in which, as it appears to us, it could be improved and amplified without seriously adding to its bulk. The number of such points may seem rather large, but in this it is like every other treatise on its first appearance ; and we hope that the authors will believe that the statements above are not made in any carping spirit, but rather as marking appreciation of what is, within its scope and purpose, really an excellent work.

A. GRAY.