Maxwell and Modern Theoretical Physics.*

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I FEEL greatly honoured in being given this opportunity of paying a tribute of reverence to the memory of James Clerk Maxwell, the creator of the electromagnetic theory, which is of such fundamental importance to the work of every physicist. In this celebration we have heard the Master of Trinity and Sir Joseph Larmor speak, with the greatest authority and charm, of Maxwell's wonderful discoveries and personality, and of the unbroken tradition upheld here in Cambridge connecting his life and his work with our time. Although I have had the great privilege, in the years of my early studies, of coming under the spell of Cambridge and the inspiration of the great English physicists, I fear that it may not be possible for me to add anything of sufficient interest in this respect, but it gives me very great pleasure indeed to be invited to say a few words about the relation between Maxwell's work and the subsequent development of atomic physics.

I shall not speak of Maxwell's fundamental contributions to the development of statistical mechanics and of the kinetic theory of gases, which Prof. Planck has already discussed, especially as regards Maxwell's fruitful co-operation with Boltzmann. It is only my intention to make a few remarks about the application of the electromagnetic theory to the problem of atomic constitution, where Maxwell's theory, besides being extremely fruitful in the interpretation of the phenomena, has yielded the utmost any theory can do, namely, to be instrumental in suggesting and guiding new developments beyond its original scope.

I must, of course, be very brief in commenting upon the application of Maxwell's ideas to atomic theory, which in itself constitutes a whole chapter of physics. I shall just recall how successfully the idea of the atomic nature of electricity was incorporated into Maxwell's theory by Lorentz and Larmor, and especially how it furnished an explanation of the dispersion phenomena, including the remarkable features of the Zeeman effect. I would also like to allude to the important contribution to the electron theory of magnetism made by Prof. Langevin, whom we much regret not to be able to hear to-day. But above all, I think in this connexion of the inspiration given by Maxwell's ideas to Sir Joseph Thomson in his pioneer work on the electronic constitution of matter, from his early introduction of the fundamental idea of the electromagnetic mass of the electron, to his famous method, valid to this day, of counting the electrons in the atom by means of the scattering of Röntgen rays.

The developments of the atomic theory brought us soon, as everybody knows, beyond the limit of direct and consistent application of Maxwell's theory. I wish to emphasise, however, that it was just the possibility of analysing the radiation phenomena

provided by the electromagnetic theory of light which led to the recognition of an essentially new feature of the laws of Nature. Planck's fundamental discovery of the quantum of action has necessitated, indeed, a radical revision of all our concepts in natural philosophy. Still, in this situation, Maxwell's theory continued to provide indispensable guidance. Thus the relation between energy and momentum of radiation, which follows from the electromagnetic theory, has found application even in the explanation of the Compton effect, for which Einstein's idea of the photon has been so appropriate a means of accounting for the marked departure from the classical ideas. The use of Maxwell's theory as a guide did not fail either in the later stage of atomic theory. Although Lord Rutherford's fundamental discovery of the atomic nucleus, which brought our picture of the atom to such wonderful completion, showed most strikingly the limitation of ordinary mechanics and electrodynamics, the only way to progress in this field has been to maintain as close contact as possible with the classical ideas of Newton and Maxwell.

At first sight it might perhaps look as if some essential modification of Maxwell's theory was needed here, and it has even been suggested that new terms should be added to his famous equations for electromagnetic fields in free space. But Maxwell's theory has proved far too consistent, far too beautiful, to admit of a modification of this kind. There could only be a question, indeed, of a generalisation of the whole theory, or rather of a translation of it into a new physical language, suited to take into account the essential indivisibility of the elementary processes in such a way that every feature of Maxwell's theory finds a corresponding feature in the new formalism. In the last few years, this aim has actually been attained to a large extent by the wonderful development of the new quantum mechanics or quantum electrodynamics, connected with the names of de Broglie, Heisenberg, Schrödinger, and Dirac.

When one hears physicists talk nowadays about 'electron waves' and 'photons', it might perhaps appear that we have completely left the ground on which Newton and Maxwell built; but we all agree, I think, that such concepts, however fruitful, can never be more than a convenient means of stating characteristic consequences of the quantum theory which cannot be visualised in the ordinary sense. It must not be forgotten that only the classical ideas of material particles and electromagnetic waves have a field of unambiguous application, whereas the concepts of photons and electron waves have not. Their applicability is essentially limited to cases in which, on account of the existence of the quantum of action, it is not possible to consider the phenomena observed as independent of the apparatus utilised for their observation. I would like to mention, as an example, the most conspicuous application of Maxwell's ideas, namely,

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the electromagnetic waves in wireless transmission. It is a purely formal matter to say that these waves consist of photons, since the conditions under which we control the emission and the reception of the radio waves preclude the possibility of determining the number of photons they should contain. In such a case we may say that all trace of the photon idea, which is essentially one of enumeration of elementary processes, has completely disappeared.

For the sake of illustration, let us imagine for a moment that the recent experimental discoveries of electron diffraction and photonic effects, which fall in so well with the quantum mechanical symbolism, were made before the work of Faraday and Maxwell. Of course, such a situation is unthinkable, since the interpretation of the experiments in question is essentially based on the concepts created by this work. But let us, nevertheless, take such a fanciful view and ask ourselves what the state of science would then be. I think it is not too much to say that we should be farther away from a consistent view of the properties of matter and light than Newton and Huygens were. We must, in fact,

realise that the unambiguous interpretation of any measurement must be essentially framed in terms of the classical physical theories, and we may say that in this sense the language of Newton and Maxwell will remain the language of physicists for all time.

I do not think that this is a proper occasion to enter into further details regarding these problems, and to bring new views under discussion. In conclusion, however, I am glad to give expression to the great expectation with which the whole scientific world follows the exploration of an entirely new field of experimental physics, namely, the internal constitution of the nucleus, which is now carried on in Maxwell's laboratory, under the great leadership of the present Cavendish professor. In the fact that nobody here in Cambridge is likely to forget Newton's and Maxwell's work, we see perhaps the very best auguries for the continued success of these endeavours. Even if we must be prepared for a still further renunciation of ordinary visualisation, the basic concepts of physics which we owe to the great masters will certainly prove indispensable in this new field as well.

The Temples of Yucatan: Work of the Scientific Restorer.

ALL the great eastward-jutting promontory of Yucatan and Quintana Roo is covered with the ruins of stone temples, erected by architects of great skill, and often beautifully decorated with carvings and wall paintings. Lying between the Usumacinta River and the Caribbean, the region is a low tableland of limestone, scarcely raised from the sea, its general flatness relieved only by a few hills two or three hundred feet high; no rivers run in all the promontory, the abundant rain falling between May and December soaking through the thin layer of soil—frequently no more than a few inches deep—to the natural limestone hollows that serve Yucatan as wells. Sub-tropical, genial, extremely productive where any soil exists, the country's wild covering is light woodland, with peculiar and beautiful vegetation, sheltering hosts of birds and beasts.

This is the background of one of the great puzzles of the history of mankind. For while the evidence is rich, and almost endless, of the high accomplishments of a brilliantly artistic people, the early origins of these people, the reason of their coming to Yucatan, and the causes for the abandonment of site after site, are still mysterious. The most plausible suggestions are no more than guesses, and none is even reasonably adequate to explain the undoubted fact that the builders of many a splendid complex of pyramids and temples appeared in the region, set to work to cut—with stone tools, for these superb architects and masons did not know the use of metal—huge masses of stone; to transport these masses, by man-labour, since they never had the help of the wheel; to set up and carve and paint great buildings; to house and worship their gods, and to practise their astronomical skill; and that after sometimes no

more than a hundred years or so, priests and builders marched away, leaving the stately buildings to become the haunt of wild creatures, to be overgrown with trees and forgotten.

According to the calculations of modern archaeologists, the erection by the Maya of stone temples (probably preceded by structures of less enduring materials, such as wood and thatch) began before the Christian era; and certain temples in Yucatan were still in occupation, as great religious and civic centres, in the early part of the sixteenth century, when the first Spaniards arrived. From the time of the Spanish conquest, the Maya and their culture suffered eclipse. A sponge was passed over the long record of their scientific and artistic attainments. With a few exceptions, to which students of American archaeology owe a debt, the Spanish conquerors felt no curiosity concerning the ideas and civilisation of the vanquished people of Yucatan. They were heathen, their gods were idols; and the great pyramids merely served, when their uplifted temples were despoiled, as quarries for building material and sites for Christian churches.

The clan of learned men, priest-kings, adepts in astronomy, disappeared. They were not only the political leaders, but also the repositories of historical knowledge, experts in the art of recording. The Maya, alone among native American races, possessed a writing method, developed into an accurate system, concerned with historical and calendrical records. These records were carved in stone, and sometimes in wood, engraved in pottery, and painted upon parchment and upon paper made from the leaf of the maguey plant. The latter, collected sedulously by the Spanish missionaries, were burnt in heaps in the market-