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> "*To the solid ground*
> *Of Nature trusts the mind which builds for aye.*"—WORDSWORTH.

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Scientific Worthies.

XLII.—HENDRIK ANTOON LORENTZ.

THE outstanding leader in physical science who is the subject of this notice was born at Arnheim in Holland on July 18, 1853, graduated at Leyden in 1875, became Professor of Mathematical Physics at that University as early as 1878, discharged the duties of that Chair with great brilliancy until his appointment a few years ago to the direction for research in the historical Teyler Institute at Haarlem, leaving Ehrenfest as his successor. He retains his connexion with Leyden as Honorary Professor, and does not treat that position as a sinecure : the weekly lecture delivered by him, and usually reported for publication by members of his audience, is one of the outstanding events in the University life. At Haarlem he leads the philosophic life, enjoying the society of his grandchildren, controlling the physical side of the Institute, which is also famous on the artistic side for the collection of the great local painter Franz Hals. The jubilee of his doctorate on December 11, 1900, was commemorated by the presentation of a volume of researches contributed by most of the notable cultivators of physical science in the world.

Since the middle ages the Low Countries have always been a seat of fervent and productive intellectual activity. In early times they were conspicuous for a broadening of the Catholic theological learning in the direction of humanism. Later, in the congenial soil provided by the achievement of ordered political liberty, they became a focus of Protestant learning, which under the stimulus of free controversy broadened out into the domains of Jurisprudence and Polity. Holland was the peaceful refuge of students such as Descartes and Spinoza : its free press played a principal part in the spread of learning in Europe, and was even the means of original publication of some of the writings of Galileo. In physical science Huygens was one of an illustrious international company which included his contemporary Newton, and ranks next among his peers both in dynamics and in optics. In our own days the eminence of Holland in physical science is maintained by H. A. Lorentz, H. Kamerlingh Onnes, P. Zeeman, and others of a brilliant band who have been, in the main, products of the great University of Leyden which dates from the times of national revival.

In his early days contemporaries in this country to whom Dutch sources were not very accessible owed their knowledge of Prof. Lorentz's writings mainly to expositions and discussions by a kindred spirit the late Lord Rayleigh, and subsequently by Lodge in connexion with his thorough experimental scrutiny of the relation of the Earth's motion to the aether, regarded as the seat of propagation of the rays of light by which we explore the universe. No trace could be anywhere found of exception to the principle that Lorentz favoured as the basis of optical theory, that the aether is a stationary medium: material bodies must thus be structures of molecular texture so open that, in the simile of Thomas Young when he pleaded in 1800 for a revival of the wave theory of Huygens, the aether penetrates through moving matter as freely as the wind through a grove of trees. The republication of some of Prof. Lorentz's early investigations, in which historical exposition and criticism are so happily blended with new advance, in vol. i. of his "Abhandlungen über theoretische Physik" in 1907 revealed, at any rate to one student, how much research into sources might have been saved him by earlier access to the *Archives néerlandaises* of 1887.[1] The volume also presented much unpublished material. There is for example a treatise on the Second Law of Thermodynamics and its relation to Molecular Theory, pp. 202-298. Nothing could be more valuable, for students who desire a real grasp of this fascinating subject, than connected exposition by a master, on general lines freed from excursions into detail.

This work was doubtless even fresher then than now, when the principles the scope of which is so universal have been sifted and refined in all directions in so many essays and text-books. The power and simplicity of the foundations of pure thermodynamics have at all times been a magnet to the most powerful minds, from Kelvin who persisted with the prescience of genius in hunting out and rediscovering in Paris the master tract of Sadi Carnot, down through Clausius, Maxwell, Helmholtz, Willard Gibbs. One can recall the crucial fundamental concept of Available, in contrast with Dissipated, Energy, introduced in a fragmentary way by Kelvin, whose wealth of fresh thoughts and of practical interests scarcely ever allowed him a chance of systematically developing any subject; its relation to the more convenient analytical concept of Entropy introduced by Clausius, and its physical elucidation in terms of a science of molecular statistics by Boltzmann and Gibbs; the luminous expositions and developments of Rayleigh; the theoretical outlook of Gibbs, vast enough to predict a full-blown new science of Physical Chemistry before it had come to birth; even such questions of pure logic as the intimate essential connexion of the principle of Carnot with the identification of heat as energy which came finally twenty years later. One remembers a remark of Prof. Lorentz in relation to an obituary exposition of Kelvin's early activity, that he had not been aware that this side of the subject had been so fully grasped at that early date.

In this historical feeling which has led Prof. Lorentz so frequently to interweave his own contributions to knowledge into a reasoned analysis of the actual position of the science at the time, close affinity may be traced with the work of Lord Rayleigh. For both of them, perhaps especially for the latter, an essential interest of human learning is the story of its historical evolution: nothing is so attractive as to recognise, still more to discover, the early insight of genius into problems usually thought to belong to later times. To both of them it appears to have been at least as congenial to explore and improve a wide field of knowledge, as to engage in strenuous special calculations such as are the very essence of progress in dynamical astronomy: though neither of them shirked such tasks when they presented themselves. Perhaps nowadays appreciation of the past is more than ever necessary to balance the haste of the present.

Of late years Prof. Lorentz's activity has been much turned by public demands into the direction of formal courses of lectures at University centres, in which his own thoughts and ideas are happily embedded. Thus the standard treatise on the Theory of Electrons arose out of lectures at Columbia University, New York, in 1905; several courses have been published in German; and a most interesting and concise reasoned account of the state of knowledge and speculation regarding statistical thermodynamic theories, leading up through Brownian movements and local fluctuations of energy into the mysteries of quanta, delivered at the Collège de France in 1912, came to be issued in French from Leipzig with additional notes in the year 1916. Earlier discussions on this latter subject (Abhandlungen, vol. i.) followed the lines developed also

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[1] "Influence du mouvement de la terre sur les phénomènes lumineux": Abhandlungen, i. pp. 341-394.

by Maxwell, Boltzmann, Rayleigh, Gibbs, which originated this domain of knowledge and, though now beset with fundamental experimental difficulties, are still the ultimate foundation of our ideas. The articles "Maxwells Electromagnetische Theorie" (June 1903) and "Elektronentheorie" (December 1903) in the Mathematical Encyclopædia are standard treatises.

His doctor's dissertation (1875) was a treatise (177 pp.) on the reflection and refraction of light, which was abstracted at considerable length by E. Wiedemann in his *Beiblätter,* vol. i., 1887. Proceeding from Helmholtz's form of the Maxwell theory, it develops a hint contained in a footnote in Helmholtz's first memoir, that the interfacial conditions of the electric theory are precisely those that lead naturally to Fresnel's standard laws of reflection. Transmission in metals also comes under review, and the laws of reflection from their surfaces; following up Maxwell's remark that gold leaf is far more transparent for the rapid electric alternations in light than its steady electric resistance would lead one to expect. It is curious that Maxwell himself has nowhere indicated the application of his theory to the dynamically fundamental subject of reflection. In a letter of 1864 to Stokes[2] in which he hints at his electric theory, then taking form, he remarks: "I am trying to understand the conditions at a surface for reflection and refraction, but they may not be the same for the period of vibration of light and for experiments made at leisure."

Other early papers published in Dutch, and reported in the *Beiblätter* by long abstracts, include a discussion of the propagation of sound according to the kinetic theory of gases (1880), and a note (1882), stimulated by a discussion of Korteweg, on formulæ for the interaction between two electrodynamic elements constructed after the manner of that of Ampère.

The famous memoir in which he applied for the first time considerations relating to discrete molecules to electric propagation in material bodies, and incidentally arrived at a rational refraction-equivalent $(\mu^2-1)/(\mu^2+2)\rho$ for each substance, independent of its density, is abstracted by himself in *Annalen der Physik,* ix., 1880, pp. 641-684. Here again the version of Maxwell's theory developed in the first of Helmholtz's critical memoirs (1870) is followed, possibly as being more accessible outside England. Indeed the expression for the refraction-equivalent is largely independent of any particular theory of propagation in the molecular medium; as is illustrated by the fact that his formula was identical with a result deduced ten years earlier in Danish on lines of elastic solid theory by his namesake L. Lorenz. The discussion of its range verified the rough substantial invariance of this expression even for change from the gaseous to the liquid state, and showed that it provides an additional atomic constant persisting through many types of chemical bonding of the atoms. This is now of course a large domain in physical chemistry.

The contribution of a vibrating molecule to the radiation is treated, after the manner of the general Stokes-Kirchhoff equations, in close correspondence as it happens with the familiar later formulation of Hertz for a dipole vibrator emitting electric radiation. Extension to include optical dispersion is considered. The result, already known to the masters, is enforced that Cauchy's statical theory which ascribed dispersion to a sensible value of the ratio of molecular distance to wave-length, is for actual matter entirely insufficient, unless as he remarks the laws of attraction are quite changed at molecular distances: but its effect is not absolutely null, and it is pointed out that cubic crystals, which are isotropic on Maxwell's theory, should on this account exhibit a small secondary double refraction of very symmetric type. Recently Prof. Lorentz has returned to this topic, and announced the detection of this quality, amidst others due perhaps to imperfection of the crystal, in his laboratory at the Teyler Institute. The detailed investigations of Rayleigh (1892) on atomic obstacles arranged in lattices stop short of the approximation here required. Later both Lorentz and Rayleigh noted that a perfect crystal should not scatter at all the light passing through it.

A static theory being thus inadequate, dispersion has to be ascribed to resonant vibration excited in the molecular structures. He works out as an example the very simplest ideal case, that of an electric charge e attracted to a massive nucleus by elastic force proportional to distance; which is the identical illustration that served him nearly twenty years later to elucidate the Zeeman magnetic spectral effect and the polarisation of the emitted radiation. The result of course also provides an illustration of the anomalous or selective refraction discovered by Kundt, which he does not then notice, restrained possibly by our ignorance which he remarks of the actual structure of molecules. Nowadays the argument for the Lorentz refraction-equivalent is made almost intuitive by correlating it with the equivalent $(K-1)/(K+2)\rho$ for the dielectric inductance K, usually ascribed to Mosotti and to Clausius. No demonstration could however be simpler than the one given even earlier by Maxwell in 1873 for the cognate problem of the conductance of a medium filled with small spheres of different material: "Elec. and Mag." i., § 314.

In 1884 Prof. Lorentz directed his attention to the

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[2] "Scientific Correspondence of Sir George Stokes," vol. ii. p. 26.

effect which magnetisation exerts on the polarisation of reflected light, discovered by Kerr in 1878, and discussed immediately after on the basis of general theory by FitzGerald but only for transparent media. A magneto-optic constant had to be introduced for each metal, naturally of complex type, which might be regarded as continuous with the constant of the Hall effect for a steady field. Experimental research, based on his formulæ, was started in the laboratory of Prof. Kamerlingh Onnes by Sissingh in 1886, in collaboration from 1889 with Zeeman: and their results are finally reported in *Archives néerlandaises*, 1894. Everything connected with magneto-optics excited great interest in England from the time of Faraday's fundamental discovery, and the stimulating dynamical speculations of Kelvin (and Maxwell, "Elec. and Mag." ii.) connecting it with a rotatory molecular theory of magnetism. The discovery of Kerr intensified the interest. The very exact material provided by Sissingh and by Zeeman was available as a test for a concentrated theoretical formulation. One may be permitted to claim that the most systematic theoretical development and thorough verification of the subject, remarkably consistent on all sides, is in a Cambridge Fellowship dissertation by J. G. Leathem, Phil. Trans., 1897, pp. 89-127, which has scarcely received the attention that it deserves. This theory attains even to features of exact prediction, which had been anticipated in a dissertation in Dutch by C. H. Wind shortly before.

About 1897 came the cardinal discovery of the effect of a magnetic field on spectra, by Zeeman, which was worked out in the early stages in the light of Lorentz's theoretical guidance. As already remarked, the elementary illustration by a single vibrating ion under elastic control, which covers all the normal features of the Zeeman subdivision, had been used to illustrate optical dispersion long before. The results admit of easy extension to any system of electrons describing interacting free orbits, however complex, about a massive positive nucleus. When there are more than three components in a spectral line, the vibrating system must be more complex. The application of the theory of the small vibrations of general dynamical systems, which suggests itself at once, gave no help and it was scarcely to be expected that it would. Recent schematic solutions employing the language of quasi-periodic systems are said to cover thoroughly the whole ground: it would be most interesting to have Prof. Lorentz's reasoned views on the promise held out by this rather inscrutable type of analysis. One observes that he uses here as elsewhere the well-tried method of discussion by mirror images, to fix the types of symmetry (cf. *Astrophys. J.* 1899): the magnetic field is reversed in the image in order to avoid change of signs of all the charges, which would lead to negative nuclei and positive electrons.

There is a paper of 1892 in *Ann. der Physik* on refraction across thin metal prisms, in which one discovers a discussion of an essential point often sought for, namely, the influence on the direction of propagation by rays of the steep gradient of amplitude along the phase-front of the emergent train. The introduction to this paper is on lines now strangely familiar; an investigation of what type of differential equations one is formally restricted to by the principle of invariance alone, in order to give rise to simple trains of damped undulations in an isotropic absorbing medium.

We come now to the two famous memoirs "La Théorie électromagnétique de Maxwell et son application aux corps mouvants," *Archives néerlandaises* 1892 (pp. 189) and "Versuch einer Theorie der elektrischen und optischen Erscheinungen in bewegten Körpern," 1895 (pp. 139), both published as separate treatises. Both of them proved to be very difficult, in comparison with previous memoirs on cognate matters, partly on account of the strangeness and complexity of the notation and analytical processes to English readers saturated with Maxwell's notation and his more intuitive procedure. One might perhaps guess that both of them were worked up gradually, as seems to have been Prof. Lorentz's custom, out of professorial lectures: for they include digests of previous papers. The main feature in both is the expansion of the Maxwell theory on the basis of mobile elementary ions, regarded simply as coherent volume distributions of electricity, as the sources of the field. That point of view had already been clearly expressed in the paper of 1878-80 on refraction-equivalents and incidentally on the explanation of dispersion, but was then developed more in terms of attractions at a distance after Helmholtz. As regards the dynamical side, both memoirs proceed through the principle of d'Alembert in a form which makes it to some extent a substitute for minimal Action. Looking through them in the light of to-day the second, which appeared early in 1895 and referred largely to optical phenomena, seems much the more striking. Thus he recognises that the Maxwell stress for free space does not balance when the state of the system is not steady, unless a quantity which Poincaré afterwards described as a distribution of a momentum connected with the stress is taken into account: this was the beginning of the stress-energy-momentum tensor. The correction in the Fresnel convection-coefficient for transparent media is obtained, arising from dispersion, which in recent years Zeeman has fully verified. All kinds of optical convective phenomena are closely considered.

But the main result is the establishment of a systematic correspondence between the electrodynamic fields of a material system at rest in the aether and the same system convected with a uniform velocity v. The result in its simple form holds only up to the first order of v/c. The fields are not identical, unless certain of the vectors are ignored as being unreal and merely mathematical expressions. But he points out that all relations concerned with the interactions of matter, such as alone experiment could test, are unchanged by the convection. This is the first systematic appearance of the electrodynamic principle of relativity. It can be extended in modified form with confidence to the second order of v/c, at any rate on an electric theory of matter, for the electrons within the atom are still small enough compared to their distances apart to be treated as point charges; and that covers the whole practical field except the domain of β rays. But when, as Prof. Lorentz noted in 1904, the truth of the result as thus extended is found to hold for the field up to all orders, the completion of this exact correspondence to include the atomic structure has to become a postulate or assumption: that was the birth of the modern efforts towards unrestricted convective relativity as an abstract formulation holding far beyond experimental verification.

There is a striking formal analysis near the end for the effect of convection on rotational optical media. For an isotropic medium the ordinary rotational modulus will be altered, and also a new rotational effect involving interaction of the vector velocity of convection with the vectors of the field can arise. As the result is of the first order in v/c, it is difficult to see how it could exist on a purely electric theory of atomic structure; so that the two formal effects should cancel. It appears that the experiments of Mascart (1872) were scarcely adequate to verify this absence of effect. Anyhow the principle of electrodynamic relativity repudiates any effect altogether.

Hitherto the transformation, up to the second order, for convection was ascribed to the molecular system, the frame of reference of space and time remaining invariable. For steady states of the system, in which time does not come into consideration, it meant a shrinkage along the direction of convection: changes so rapid that the alteration of the measure of time could be effective scarcely occurred, and were put aside. When Prof. Lorentz pointed out that the transformation, which is now known by his name, was exact as regards electrodynamic fields in free space, and also exact to some extent when there are electric densities in the field, the subject took on a new and wider trend. The transformation was transferred by Einstein (in recent years attached to Leyden as part-time Professor) to the frame of space and time instead of the molecular aggregations of matter, each taken separately, which accidentally occupied it. The question is then no longer confined to shrinkage of the material frames of terrestrial experiments: effects must be expected over astronomical distances across empty space. Adaptation of the Newtonian law of gravitation into a form invariant for the fourfold space-time frame of Minkowski, which was the final analytical consolidation of this aspect of the subject, was effected by Lorentz and by others with a view to search for astronomical indications, and in particular to find out whether the outstanding minute secular rotation of the orbit of the planet Mercury, already the standard test for modified laws of gravitation, became amenable. The changes thereby introduced proved to be of small account.

Meantime Einstein seems to have been struggling to get rid of the Minkowskian uniform universal space-time, which was just as absolute in its combined four dimensions as was the Newtonian scheme of separate space and time. By identifying locally the essential features of a physical field with intrinsic differential constructs in the fourfold expanse, named tensors, of which a formal calculus had already been fully developed by Ricci and Levi-Civita, he was able finally to select a group of related local tensors as the result of tentative adaptations so as to exhibit the now famous view of gravitation as represented by warping of the fourfold pseudo-spatial expanse around the material nuclei. Though this can scarcely be said to have explained gravitation, it has been widely held to have explained (or abolished) space and time: it merely forced gravitation, just as it happens to exist, into the electrodynamic frame with its property of insensibility to uniform convection, with no detriment to the results of Newtonian physical astronomy and a rather better account of the problem of the Mercury perihelion.

This empirical building up of a field of gravitation out of tensorial constructs belonging to a space-time expanse, now differentially heterogeneous, was completed by adapting the Minkowskian vector potential of the pervading electrodynamic and optical field to the same conditions. The need for a more physical setting, at any rate to those who believe in minimal Action as the ultimate and necessary binding principle in physical analysis of a molecular world, seems to have been met immediately to a considerable extent by Lorentz and soon after by Einstein himself and by Hilbert. "The discussion of some parts of Einstein's theory of gravitation may perhaps gain in simplicity and clearness, if we base it on a principle similar to that of Hamilton. . . . Now that we are in possession of Einstein's theory we can easily find how this variation principle must be formulated for systems of different nature and also for the gravitation field itself" (Proc. Amsterdam Acad., Jan. 30, 1915). This is not the place to pursue the contentious view (cf. *Phil. Mag.*, Jan. 1923) that the Least-Action dress, just because it is so closely interwoven, is like the shirt of Nessus, and tends to make havoc of the spatial philosophy though without destroying the tentative validity of the elegant analytical method. Possibly Prof. Lorentz may be tempted to unravel this question in his admirable judicial manner.

In the subsequent years the Proceedings of the Amsterdam Academy became a focus for the literature of the gravitation theory, mainly in a series of papers, apparently first delivered as lectures, by Prof. Lorentz himself, in which he develops the tensor scheme in an elegant way of his own by a differential geometry involving use of infinitesimal loci of constant geodesic radius as a kind of indicatrix. Among many other papers, doubtless arising from a common inspiration, one recalls Droste's determination, simultaneous with Schwarzschild's solution, of the exact gravitational field of a particle, and Nordström's of the field of an electron.

One can look back, still with undiminished surprise, at the vast mass of intricate literature on this subject which flowed westward, mainly from Berlin and Leyden and Göttingen (and also from Italy), when Central Europe was again thrown open after the end of 1918. The difficulties of a strange though potent and elegant calculus could be surmounted by application; but the mysteries of unfamiliar meanings and implications in imaginary space and time could give rise to abundant misconceptions. The uninitiated must still be wary in approaching this unexplored and treacherous domain, in which Prof. Eddington has recently detected for us, by beautiful analysis of algebraic tensors, how mere co-ordinates are liable to undulate across the field on their own account entangled with the gravitational waves in the underlying spatial reality.

There is no space to pursue this review of Prof. Lorentz's work further. A survey of his activity is a liberal education in the history of physical science for the last half-century. Reference to the Proceedings of the Amsterdam Academy for the last twenty years, in the handsome form of the edition in English, will reveal the breadth and informative character of his investigations. But this series of volumes is long and portly; and he would confer a great boon on students of physical science the world over if he could manage to continue the edition of Collected Papers of which the first volume appeared in 1907. He will be excused the task of reconstruction to bring them up-to-date which he then essayed, and which perhaps has been a cause of the delay.

Needless to say, Prof. Lorentz has attained to all the distinctions all over the world that are appropriate for a man of science. He has long been a Foreign Member of the Royal Society, and is in the lists of Rumford and Copley medallists. For the working congresses on the theories of physical science that are a feature of our time, he is an almost indispensable chairman. Great linguistic gifts, abounding learning, clear and rapid grasp of a point of view and prompt exposition of it in a different language, ease of approach, tolerant appreciation and encouragement of speculations still unverified, are familiar to his scientific colleagues. We may hope that his time will not be diverted overmuch to administrative work such as could be done by others.

JOSEPH LARMOR.

The Botanical Survey of British Malaya.

The Flora of the Malay Peninsula. By H. N. Ridley. Vol. 1: *Polypetalæ.* Pp. xxxv + 918. (London: L. Reeve and Co., Ltd., 1922.) 63*s.* net.

THE Malay Peninsula, for which the opening volume of a Flora by Mr. H. N. Ridley has been published "under the authority of the Government of the Straits Settlements," is an important and, save for the narrow northern section nearest Siam, a typical province of the Tropical Rain-Forest Region. Though Europeans secured a footing in this Peninsula four centuries ago, the survey of its vegetation was long deferred. The Portuguese, who occupied Malacca in 1511, had done little before their expulsion by the Dutch in 1641. The Dutch, who, with two short breaks (1795–1801 and 1807–18), owned Malacca till 1825, scarcely did more. Rumpf, whose "Herbarium Amboinense" (1750), completed on September 20, 1690, surveys the vegetation of the Malay Archipelago, avoided dealing with Malacca. Rumpf regarded the Malay Peninsula as belonging to continental India, and Valentijn, in his "Oost-Indien" (1726), held the same view.

The British became interested in the Peninsula when Penang was acquired in 1786. Sir Joseph Banks, president of the Royal Society, satisfied the directors of the East India Company that a survey of the vegetable resources of their territories was essential, and in 1793 the Calcutta Botanic Garden was permitted to add survey operations to its acclimatisation work. The investigation of the vegetation of the Peninsula, then begun in Penang, was extended to Malacca when that Settlement was first captured from the Dutch in 1795, and to Singapore when that Settlement was