

H. A. Lorentz

H. A. LORENTZ
IMPRESSIONS OF HIS
LIFE AND WORK

edited by

G. L. DE HAAS-LORENTZ



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With reverence and affection

PREFACE

Among the physicists who at the turn of the century enlarged the compass of physical science and opened the roads along which the stupendous advance of atomic physics was going to proceed, H. A. Lorentz takes a prominent place. Many of his results have become staple knowledge, his collected works show the width of his interests, but yet his publications reveal only partly what he has meant to his contemporaries. In his own country, little given to hero-worship though it may be, even the man in the street venerated him; in the international world of science he commanded universal respect to a degree attained by few others.

It was the late J. C. Clay, who, at the time of Lorentz' centenary, suggested that those who had had the privilege of knowing him personally should try to write down their reminiscences. The result of Professor Clay's initiative is the present volume, to which, however, he himself has unfortunately been unable to contribute. It is not in any way an attempt at a complete biography or at a systematic evaluation of Lorentz' works, but it tries in the form of an anthology to recreate the impression of his personality. To me it seems that these recollections, which portray a charming, modest and unusually gifted man, are of special interest because they deal with a man living in a transition period. Some physicists like Einstein and Bohr would even today decidedly be called "modern", others are now regarded as "classical", but Lorentz was both the one and the other. In the essay which concludes this volume I have tried to analyse this feature of his work in more detail, but it is also in evidence in his personal

life; the retired and almost solitary studies of his younger years in contrast with his later international activity. His life began when the industrial revolution had hardly started to make an impression on Dutch provincial towns, it ended in an era of electricity, cars and airplanes, yet throughout his life Lorentz was neither a revolutionary nor was he left behind by the stream of events. In a rapidly changing world he remained a leader without ever losing the serenity of his early years.

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Finally the authors would like to acknowledge their indebtedness to Albert Einstein who shortly before his last illness had promised his co-operation and thus encouraged the writing and publication of this book.

H. B. G. CASIMIR

¹⁾ Mr. before a name is the Dutch abbreviation of magister, which indicates that the person in question is "legum doctor" or "doctor iuris". In England the abbreviation LL.D. is used, placed after the name.

H. A. LORENTZ, HIS CREATIVE GENIUS AND HIS PERSONALITY

BY

A. EINSTEIN

At the turn of the century, H. A. Lorentz was regarded by theoretical physicists of all nations as the leading spirit; and this with the fullest justification. No longer, however, do physicists of the younger generation fully realise, as a rule, the determinant part which H. A. Lorentz played in the formation of the basic principles of theoretical physics. The reason for this curious fact is that they have absorbed Lorentz' fundamental ideas so completely that they are hardly able to realise to the full the boldness of these ideas, and the simplification which they brought into the foundations of the science of physics.

When H. A. Lorentz started to write, Maxwell's theory of electromagnetism was already generally known. This theory, however, suffered from a curious fundamental complexity, which prevented its essential features from being conspicuously clear. True, the vectorial field concept had ousted that of action at a distance; but the electric and the magnetic field were not yet conceived

as being original entities, but as conditions governing ponderable matter, which was treated as existing in a continuous form. As a result, the electric field appeared to be split into the vector of the electric field strength and the vector of dielectric displacement. In the simplest case, these two elements were linked together by the dielectric constant; in principle, however, they were regarded and treated as two independent entities. Similar ideas prevailed in respect of the magnetic field. In conformity with this basic conception, empty space was treated as being a special case of ponderable matter, in which the relation between field strength and displacement only appeared to be particularly simple. And, more especially, this conception entailed that the electric and the magnetic field could never be conceived as independent of the state of movement of matter, which was regarded as the carrier of the field.

A study of Heinrich Hertz' investigation into the electrodynamics of moving bodies will give the reader a clear insight into the conception, prevalent at that time, concerning the electrodynamics of Maxwell.

It was here that H. A. Lorentz' act of intellectual liberation set in. With great logic and consistency he based his investigations on the following hypotheses:

The seat of the electromagnetic field is empty space. In this field there is only *one* electric and *one* magnetic field vector. The electromagnetic field is created by atomistic electric charges, to which the field, in turn, reacts pondero-motorically. The only link between the electro-motoric field and the ponderable matter lies in the fact that elementary electric charges are intimately bound up with the atomistic constituents of matter. For the latter, Newton's law of motion is valid.

On this — thus simplified — foundation Lorentz based a complete theory covering all electromagnetic phenomena known at the time, including the electrodynamics of moving bodies. It is a work of rare clarity, logical consistency, and beauty, such as has been achieved only rarely in any empirically based science. The only phenomenon whose explanation could not be given completely — i.e. without additional assumptions — was the famous Michelson–Morley experiment. But it would have been unthinkable for this experiment to lead to the special relativity theory without the localisation of the electromagnetic field in empty space. The really essential step forward, indeed, was precisely Lorentz' having reduced the facts to Maxwell's equations concerning empty space, or — as it was then called — the ether.

H. A. Lorentz even discovered the “Lorentz transformation”, so named after him, — though ignoring its group — like quality. For him, Maxwell's equations concerning empty space applied only to a given system of co-ordinates, which, on account of its state of rest, appeared excellent in comparison to all other existing systems of co-ordinates. This was a truly paradoxical situation, since the theory appeared to restrict the inertial system more than classical mechanics. This circumstance, proving as it did quite incompatible with the empirical standpoint, simply *had* to lead to the special relativity theory.

As I was frequently in Leyden on fairly long visits, thanks to the thoughtful kindness of Leyden University, and staying now and then with my dear and unforgettable

friend Ehrenfest, I often had an opportunity to attend H. A. Lorentz' lectures, which he regularly gave to a small circle of younger colleagues, after his retirement from his general professorship. Everything that emanated from his supremely great mind was as clear and beautiful as a good work of art; and one had the impression that it all came out so easily and effortlessly as I have never experienced it from anyone else.

If we younger ones had known H. A. Lorentz only as a great luminary, our admiration and veneration for him would already have been of an extremely special kind. But what I feel when I think of H. A. Lorentz is not covered by a long way by that veneration alone. For me personally he meant more than all the others I have met on my life's journey. Just as he mastered physics and mathematical structures, so he mastered also himself, — with ease and perfect serenity. His quite extraordinary lack of human weaknesses never had a depressing influence on his fellow-men. Everyone felt his superiority; no one felt depressed by it. For, although he had a keen insight into human nature and human relationships, he had a charitable kindness towards it all. His influence was never a dominating, but always a serving, helping one. He was exceedingly conscientious, without, however, making any particular matter appear unduly important. From this, he was protected by his fine sense of humour, which reflected itself in his eyes and in his smile. And it was quite in keeping with this that, with all his devotion to scientific study, he nevertheless was perfectly aware that the human intellect cannot penetrate very deeply into

the essential core of things. It was not until my later years that I was able fully to appreciate this half sceptical, half humble disposition.

Notwithstanding sincere effort, words — or, at any rate, my words — cannot do justice to the subject of this brief essay.

ON THE OCCASION OF THE
HUNDREDTH ANNIVERSARY OF THE
BIRTH OF H. A. LORENTZ¹⁾

BY

W. J. DE HAAS

The editors have requested me to put on paper a few personal recollections on the occasion of the commemoration of this day. I have stated elsewhere that this would not be easy. The personality of Lorentz did not readily yield itself to biographical description. He was never absent-minded, nor was he a professor in the common acceptance of this word. He did not want to be different from other people, which marked his greatness, because in actual fact he did differ from others to a great extent. A greater simplicity, a more positive naturalness I never witnessed, combined with a great unintentional and instinctive distance. The two went side by side, sometimes separated, then again cancelling one another into the great personality that was Lorentz.

Lorentz was not only a great scholar, with a knowledge unequalled, but also a great and fascinating personality. Kamerlingh Onnes once said to me "Look, de Haas,

¹⁾ These recollections were written at the request of the editors of the "Leidsch Dagblad" and published in their paper on January 24th, 1953. The editors were kind enough to allow me to reprint the article.

wherever your father-in-law is present, the conversation quite naturally becomes centred about him. There is nothing contradictory in this, it is self-evident and completely natural". And so it was!

Thus Lorentz was unsurpassed as chairman in a meeting. When an international group got together and ardently discussed scientific problems, Lorentz, the outstanding figure among all others, led the conversation, passing from French to English or German with the greatest ease and perfection. For then, at the head of the table, was seated a man, not only acquainted as no one else with the problems of physics, but possessing other gifts by which many a diplomat might have profited. He was tactful, conciliatory, always able to coin the happy phrase which suited the situation. How different this world would be, with its spiteful and often low quarrels, if men like this great Dutchman could occupy the top positions. For Lorentz never allowed science to interfere with human considerations. He had a great interest in those who stood lowest in the social scale. And this consideration for others did not stop at the mere rendering of financial aid, the easiest manner in which a man can discharge his duty to his fellow-men. No, it often became a matter of deep and personal concern, mostly unknown to the world around him. Many a resident of the city of Leyden can witness to that fact.

I have often thought that the very ease with which Lorentz was able to perform his work made it possible for him to remain human. He never had to make an effort to excel in order to gain the laurels which were his due. With many other scholars this likely is a different matter; fatigue, exertion and strain are often the causes why they forget what is going on in the world around them.

With Lorentz this was not the case; with him I never noticed a sign of strain or of fatigue. He was never lacking in time, although unquestionably he worked hard; but his labour was performed in a calm and effortless manner. During his younger years his working hours went far into the night, but the prolonged time given to his vast effort meant to him a prolonged pleasure, the great fulfilment of his life. Him was granted the supreme blessing of a highly superior mind, logical in every sense, methodical and precise.

Lorentz did not like to discuss things not well known to him, or matters to which he had neither given, nor tried to give his deeper thoughts. He never touched philosophy. He interpreted the idea of God in terms of humanistic reasoning. He realised full well that nature exceeds and transcends all human capacity to understand, or power to perform. But he knew to limit himself to those deep problems of science, the human mind could deal with. Here it was that later on Einstein would cross his path. It was the experience of a lifetime to watch these two brilliant men when discussing matters of common interest. And as I listened to them, and discovered how their thoughts ran parallel in many respects, it occurred to me that both men were created after one and the same great pattern. It was, indeed, a great pleasure and a high privilege to hear them.

When one looks back towards the past, how great the monotony which meets the eye! Who would still be able to tell who lectured on physics at Leyden University 160 years ago? True, one hears the name of Boerhaave mentioned in connection with the science of medicine. One is told how this scholar attracted students from all parts of the world, and how he both studied and taught

the art of healing while seated at the sick-bed of his patients. Boerhaave's statue may be seen to-day in the Boerhaavelaan overlooking the grounds of the University Clinics.

But what further information have we? In physics one has to go back to Christiaan Huygens in order to find the equivalent of Lorentz. Huygens did study at the University of Leyden, but he never filled the post of professor there. When one reads the story of Huygens' life, one senses how far inferior he was to Lorentz as a personality. Huygens was given to melancholy, while Lorentz, though not superficially gay, was courageous and cheerful. He was a great man, and a past master in the art of teaching. Huygens, as far as every-day circumstances are concerned, might be counted a privileged person. Both Lorentz and Huygens have considered all kind of problems in the field of physics and have published their results. A characteristic feature of Huygens was his interest in what at present would be called technical problems and in instruments. Lorentz' mind verged more towards the abstract, which does not alter the fact that, when the occasion called for it, he has shown unusual ability in dealing with technical problems. I may only mention the outstanding way in which he solved the problem of the increase of the tides after the enclosure of the Zuiderzee. As Professor Ir. Thyse observed, "in Lorentz' solution of this problem observation and theory fit together in a manner which is almost incomprehensible". For this single accomplishment, if he had done nothing else, our whole nation owes Lorentz gratitude.

However, Lorentz' major activity, though partly related to the very abstract field of relativity, is chiefly concerned with the problems of electricity. For quite some time

Lorentz had been convinced that the atoms of the elements contained still smaller particles, but he did not know either the sign of their electric charge or their weight. From the experiments of Zeeman he was able to derive some conclusions.

It was in the Netherlands that the concept of the electron came into being, a small particle, which, according to Zeeman's experiments at the time, proved to be one thousand times lighter than the hydrogen atom. Lorentz once told me about his amazement at the utmost smallness of the particle. But his calculations were compelling and subject to no doubt.

More recent physics have shown that other small particles exist, such as positrons, neutrons and mesons. We Dutch should not forget that the first of these small particles, which opened up a new era to natural science, was born in the spacious study in the house on the Hooigracht, where now is situated the chemist shop "Hulp der Menschheid".

How many truths, discoveries and findings have not been issued from Lorentz' inspired pen, when, in sentences perfectly formulated, the great scholar wrote down his words in a marked handwriting, the letters spaced apart. Thus this pen made him a Prince of Science, and as a Prince did the Dutch people accompany him on his last journey. In connection with his death, these words written by the poet Boutens came to my mind: "Blessed Death, whose pure notes enter into life now stilled"¹⁾. It was indeed a blessed Death which with its hand smoothed the wrinkles between being and non-being for Lorentz. He died, his matchless mind conscious to the last. The Dutch people will never again find his equal.

¹⁾ "Goede Dood wiens zuiver pijpen Door 't verstilte leven boort".

REMINISCENCES

BY

G. L. DE HAAS-LORENTZ

YOUTH IN ARNHEM

Many of my readers are acquainted with the memorials erected by the people of the Netherlands after the death of their great son, H. A. Lorentz: the monument in Sonsbeek¹⁾, the bust in Haarlem²⁾, the small statue above the entrance to the Instituut-Lorentz for theoretical physics at Leyden³⁾. They know how the name of Lorentz is perpetuated in Dutch society by countless schools, streets and squares in many towns and villages, all bearing his name. They are aware of the outstanding tribute given to his memory on the occasion of the centenary of his birth, when the locks in the enclosing dike of the Zuiderzee were named after him, to show the nation's gratitude for the important part which Lorentz had played in making the construction of this dike possible by his calculations by which its height was determined.

Those who have contacts with scientific circles will know about the Lorentz fund⁴⁾, the Lorentz medal⁵⁾, the

¹⁾ Erected in Arnhem at the initiative of rural and local committees.

²⁾ A gift from the municipality of Haarlem in 1929.

³⁾ Erected by the municipality of Leyden in 1933.

⁴⁾ Money collected by those who participated in the celebration of the golden anniversary of Lorentz obtaining his doctorate.

⁵⁾ Founded on the same occasion by the Royal Academy of Sciences.

Lorentz chair in the University of Leyden¹⁾), a Lorentz scholarship²⁾). Some of my readers may probably have heard of the almost royal homage rendered to Lorentz on the occasion of his funeral at Haarlem, when the normal flow of traffic in the city was redirected so as not to delay the funeral procession, and on account of the great interest shown by people of all classes. They may recollect how the lighted street lanterns were draped in mourning, while the bells of the churches of all denominations were tolling. And how finally, after a short, impressive ceremony, the remains were entrusted to their final resting place, a simple grave, chosen by his widow, who knew that simplicity was dear to her husband's heart.

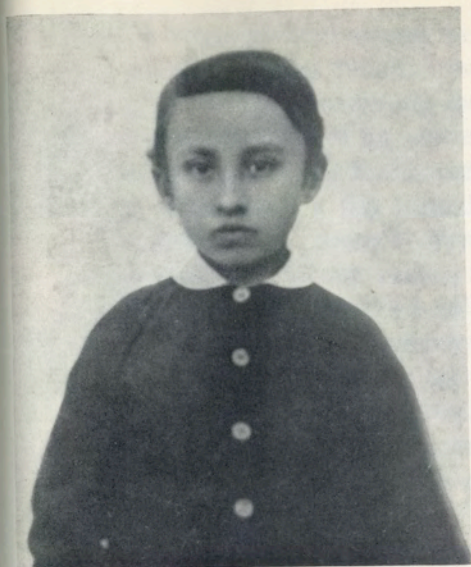
I should wish nothing more than to begin this biography with a sketch of the youth of little Hendrik Lorentz. For the account of the early years of the hero of a biography is always the most interesting part of it. How much do I regret that I know so very little of this period; my father was a very uncommunicative man, who very seldom spoke about his youth, and even less about his inner life.

Hendrik Antoon Lorentz was the son of Gerrit Frederik Lorentz, who, like his father before him, owned a nursery on the Musschenberg, close to the village of Velp near Arnhem. His mother was Geertruida van Ginkel, born in Renswoude in the province of Utrecht. She had been married before, to Jacob Janssen from Renkum. Shortly after the birth of her son Hendrik Jan Jacob, her husband died. Some years later she married again; her second husband was my grandfather, by whom she had two sons:

¹⁾ Founded by the Dutch government on the occasion of the Lorentz commemoration in 1953.

²⁾ Founded by the municipality of Arnhem on the same occasion.

About 7 years old



During the last school-year.
From left to right: Haga, de
Jongh, Lorentz

Hendrik Antoon and a second son who died at an early age. Geertruida, after whom I was to be named, died young (1857). Apparently my father must have had a lingering recollection of his mother, or was it perhaps a partly conscious longing for her rather than a recollection? Whenever he made a trip from Leyden to Arnhem he paid a visit to his mother's grave, until the cemetery, situated near the railway station, was discontinued.

Hendrik's father remarried in the summer of 1862 Luberta Hupkes, whom I owe my second Christian name, the one by which I am called. Jan, Geertruida's eldest son (Hendrik Jan Jacob) was then twelve years old; Hendrik (Hendrik Antoon) had just reached the age of nine, he was a frail little boy. The step-mother seems to have taken good care of the boys.

Together with the two boys she often visited relatives living in "de Steeg", a wonderful spot for boys to roam about in the surrounding woods. Little Hendrik soon came to know all about de Steeg and its surroundings, and later on he became equally acquainted with the whole neighbourhood of Arnhem. Since these early years, and well into his old age, his most favoured form of recreation was taking walks and trips with his friends; later he got into the habit of walking alone, or at most with one single friend. A sister of my grandfather's, Berendina Lorentz, was living in Arnhem at the time. She was married to David Henny. The Lorentz family were very friendly with them and their children, and there was a good deal of family contact. There were three children Henny: David, seven years younger than Hendrik, and two older girls. David became later an engineer and settled in Portland, U.S.A. He was very gifted and succeeded in making a great name for himself

in his profession. Among his accomplishments was the building of the Boulder Dam. It was rumoured that he might have become ambassador to his native country.

I picture little Hendrik as a quiet, cheerful child, not particularly fond of rough games with his friends, but taking part in them so as not to be a spoil-sport. He was very late in talking: when his halfbrother, who was three years older, left for school, Hendrik used to call goodbye to him in broken language. (This may serve as a consolation to parents who worry about their child when it is late in talking!)

In the fifties very few children's books existed. My father possessed only one, and he often told us how precious this book was to him. He had just learned the letters and wrote H.A.L. on every page of the book, which at the time was not considered an aid to its beauty. How different this would seem in later years when those letters would have been deemed an adornment of the front page of any book.

When he was six years old, Hendrik went to study in Master Swater's school, at that time one of the best in the city of Arnhem. He was always number one in his class, much to the delight of his parents and much to his own discomfiture: for, as a result, the task was entrusted to him to stand every morning in the doorway connecting two class rooms, which were served by the same teacher, and there to recite the morning prayer. My father told us how greatly he disliked to do this and how embarrassed he was. He even seriously considered purposely to make mistakes in his arithmetic problems so that he would be number one no longer. But when he considered the mistakes which he conceivably could make, they all seemed too silly to him and he changed his mind. At

that time an evening school was combined with the higher forms of the school. Instruction was given there to all forms by one teacher, unassisted by others. The manner of instruction resembled the Dalton method, because all assignments were finished in the school itself and not at home.

The evening school attended by my father was conducted by Master Timmer, a teacher who must have possessed remarkable talents both as an instructor and a pedagogue. Under his guidance talented boys had the opportunity of advancing in their studies by self-instruction. None of the pupils made better use of this opportunity than Hendrik Lorentz, and Master Timmer helped him in this matter as much as he could. This explains why Hendrik was able when he was but nine or ten years old to use a table of logarithms, a copy of which he had bought in the market square with his own money¹).

When Hendrik had finished this school and became thirteen years old in July 1866, the first High School had been established in the city of Arnhem. Hendrik took part in the entrance examinations and on that occasion became acquainted with Herman Haga, who was one year older. This was the beginning of a friendship which lasted throughout their lives. Both boys were placed in the third form. And now in the life of my father a period of happy years followed. By reason of his great interest in all of his studies, he easily excelled in everything he undertook. This was the reason why gradually he developed a sense of perfectly natural, calm self-assurance.

His relationship towards his teachers, particularly towards those who taught physics and chemistry, became more and more friendly. Physics was taught by H. van

¹) This little table of logarithms I still have in my possession.

de Stadt, author of textbooks for intermediary education which, though revised, were still in use eighty years later. Since 1868 chemistry was taught by the young and enthusiastic Dr. J. M. van Bemmelen, the headmaster of the school, whose instruction was thoroughly modern. My father told me with great relish that he had learned in High School that H_2O stands for water, and later at the University of Leyden, that in nature everything goes in pairs. The formula for water should therefore be one H plus one O which is HO! Van Bemmelen had previously been headmaster of the High School in the city of Groningen, where he had Heike Kamerlingh Onnes among his pupils.

One of the few things my father used to tell us, was about the happy times which he had in the fifth form in High School. It was a small class of only three pupils: de Jongh (later a district officer of the colonial government in Java, where he died at an early age), Haga and my father. When the weather was good, and when the subject under consideration lent itself to it, the lectures were given while strolling through the woods around Arnhem.

Many a discussion went on among the three friends. They read a good deal and were greatly interested in history; particularly the history of the Reformation interested my father.

Which books did he read? I seem to recollect that he spoke mostly about English books. He would refer to authors as Motley and his "History of the rise of the Dutch Republic", to Macaulay, to Carlyle and his book "On heroes, heroworship and the heroic in history" and to others of the same kind; also to Walter Scott, Thackeray and Charles Dickens. His love for Dickens Hendrik shared

with his father, who had read all Dickens' works with the greatest interest and remembered them from A to Z. His excellent memory Hendrik inherited from his grandfather. The latter's literature consisted mainly of sermons which he used to write down word for word after his return from church on Sunday. Considering that in those days people went to church twice each Sunday, these sermons came to amount to a considerable number. It was a blessing for the minister that not every member of his audience showed a like interest nor had so good a memory as my great-grandfather, for if so, it would not have remained hidden from the listeners whenever the minister tired of sermon making and was tempted to use an old one. My great-grandfather detected such practice readily, even when the sermon was many years old.

The same power of memory and the same gift to read carefully we find in my father, greatly to his profit, particularly in connection with his study of foreign languages. It is not surprising that his English teacher praised his English, adding, however, that it resembled Dickens too much. It is interesting to note in this connection that my father possessed the curious gift, through careful reading, to find out by himself the rules regarding grammar and idiomatic use of the language (try this for yourself, and see how difficult this is!) This gift often was a surprise and a great help to me.

I heard little from my father about German books. I only remember that he enjoyed the works of Fritz Reuter, Felix Dahn and both Goethe and Schiller. Of French literature he mainly read Voltaire and Erckmann-Chatrion. How consciously and deliberately he tried to make himself familiar with foreign languages is shown in the fact that he attended regularly the French Church, frankly

admitting that the chief reason was to learn French well.

The orthodox-protestant circles in which my father grew up created in him a spirit of mental independence. Add to this a total lack of mystical appreciation and a shyness to discuss spiritual convictions with others, let alone speaking of them in public, and you will readily understand how the courage and honesty of men like Luther and Melancthon transformed these historical figures into heroes in the eyes of young Hendrik. Something similar happened when the Rev. de Keyzer, one of the first liberal preachers in the city of Arnhem, came to occupy a pulpit in that city. This minister was known as a good speaker, and he must have been of outstanding character, judging from the influence which he exerted upon the younger generation. My father went to hear him, this time definitely for the sake of the sermons. My father's interest in the history of the Reformation, and the influence which liberal religion had upon him are, in my judgment, the outward signs of an inner urge to search for truth on the part of an intelligent and honest man. It was a pity that my father's critical mind could find no satisfaction even in this liberal interpretation of Christian doctrine. Faith through divine grace was denied him, and thus he died, though in peace, without the consolation afforded by that faith. The supreme value of the mind in its rightful function, and the importance of the individual life in a spiritual, though not supra-mundane sense, took with him the place of religious convictions. Life's supreme purpose to him was first of all the proper usage of the mind, if possible towards creative work (and the world knows how successful he himself has been in this respect); and in the second place to open to all others the opportunity to develop their

minds freely. We may trace this fundamental line of thought all through Lorentz' life. And yet it seems difficult to conceive how, without guidance from above, life can be rendered harmonious, and helpful to mankind, or shall we not say in this instance, to individual men. The development of the mind, and how to make it productive, taken as a problem by itself, creates a source of conflicts and obstacles. To overcome these difficulties peaceful surroundings are needed in order to protect the person involved from the influence of his own confused emotions. As far as I can judge, the outstanding conflict in my father's life were the emotions of a sensitive heart on the one side, and on the other, the urge (perhaps a gift from above after all?) towards the rigorously exact accomplishments of the reasoning mind. He solved this conflict. Whereas in the case of many people the mental creative work suffers by reason of the emotions created by the events of everyday life, this was not the case with my father, fortunately for mankind.

You will probably ask whether I have nothing to relate concerning my father's study of mathematics and physics while he was still at school. Alas, I am not able to do so! It was known that he excelled in those subjects; I learned this from his contemporaries. But how far in later years he surpassed all others in those subjects? We cannot find anyone with whom he may have discussed his ideas and who could have handed this information down to us and our contemporaries. He developed his great gifts in the field of physics without known contact with others. This must have begun already in High School. In the year following matriculation, which had to be devoted to the study of Latin and Greek in order to be able to pass the government examination for admittance to the University,

the future student surely will not have neglected the study of mathematics and physics.

STUDENT AT LEYDEN

After passing the government examination Lorentz went to study at Leyden University (1870). He was the only one of the three pupils of the fifth form of Arnhem High School. De Jongh received a different kind of training and went later on to the Dutch East Indies, while Haga was forced to repeat his examination. It was only in 1871 that he gained admittance to Leyden University. This was the reason, as we shall see presently, why my father and he were fellow students at Leyden for only a few months.

The fame of his outstanding mind had already preceded my father's arrival in Leyden and many were interested to meet this "highly gifted dark little person", who had come to study mathematics and physics. In those years the professor in the faculty of mathematics and physics who had gained the greatest reputation at home and abroad was the astronomer Professor F. Kaiser. Kaiser is known, among other things, as the founder of the present observatory¹). This fact is still remembered in the name given to the street which resulted when the small canal was filled in, on the banks of which the observatory stood, and which emptied into the Rapenburg. That the student-corporation took part in the action for the foundation of the new observatory shows the enthusiasm which Kaiser aroused in his students (see Lorentz' Commemoration Address Bosscha, 1911).

Kaiser had heard a good deal about Lorentz from his

¹) The original observatory had existed since 1632, when it was founded by Golius.

former pupil H. van de Stadt, who shortly before 1866 had received his Doctor's degree and who owed his interest in physics to his professor of astronomy. On the other hand, the stories told by van de Stadt about the brilliant lectures delivered by Kaiser aroused in my father the desire to attend them. Soon he was a welcome guest in the family circle of the professor, then already well advanced in years. Even the first official call of the young student upon his professor had done no harm. My father used to tell us about this visit, how he had found Kaiser ill with a cold and was received with the words: "Lorentz, you better do the talking this evening, I must save my voice as much as possible". A ticklish situation for a shy young student such as my father then was.

Lorentz was sociably inclined and liked companionship with people of his own age; he therefore decided to become a member of the Leyden Corps, a student association. Here too, his quick, receptive mind helped him to overcome the difficulties of the "freshman's period". I was told of one instance, when, in a large circle of students whose names had been given him just once, he proved able to repeat them without any hesitation, connecting each name with the proper person.

Yet, after one year my father decided to discontinue his membership; social life of that kind did not suit his taste and, moreover, he was too much engrossed in his work. And thus his student days passed by uneventfully. A few ties of friendship were formed, but it was again walking in the country, alone or with a single friend, which was his favourite recreation.

As far as the lectures were concerned which he attended during the first years of his student career, apart from those given by Kaiser, only those by Rijke, then the only

Professor of Physics, and by van Geer in analytical geometry, were mentioned with approbation by my father. It is noteworthy that in those days all students preparing for the Bachelor's degree were forced to take philosophy. No tests (tentamina) were required, only a statement from the professor testifying to regular attendance. This procedure resembled somewhat the practice followed when in subsequent years the Studium Generale was introduced. It is a pity that in this respect the students did not appreciate the good intention of the legislator. The conduct of the students in the lectures of the Professor of Philosophy seems to have been most disorderly.

My father's chief interest appears to have been in the lectures on theoretical astronomy. After he became acquainted with young Lorentz, Kaiser resumed these lectures which had been discontinued because of lack of interest. Soon these general lectures were changed into a *privatissimum*, with the result that no *tentamen* was required; Kaiser saw no point in this kind of mimic battle.

Lorentz passed his examination for the degree of Candidate in Mathematics and Physics, *summa cum laude*, in November 1871. A remarkable incident occurred during the preliminary oral examinations in mathematics by Professor van Geer. The latter expressed his satisfaction, but also his disappointment because his high expectations had not been fully met. Upon closer examination it proved that the professor had examined his candidate for the Doctor's degree. And, of course, there had been something lacking.

BACK IN ARNHEM

After Lorentz had passed his examination he left Leyden, not to return there as a student. Professor Kaiser, owing

to ill health, had been forced to give up his *privatissimum* and my father decided that he could study the subjects necessary for his Doctor's examination just as well by himself; in fact he preferred to do this. He therefore returned to Arnhem in February 1872 and became a teacher at the Evening High School. And now the same person, who as a little boy used to rehearse constantly the errands his mother had given him to do, while running to the shop, for fear that he would be too shy to repeat them correctly, and who as young student had found it most difficult to pass a whole evening with a professor he did not happen to know, was forced to wrestle with other difficulties. It was not easy to teach a class of boys of about his own age, and not particularly keen to study the subject under consideration. It took some time to adapt himself to this new task, but he succeeded. My father continued in this function until his final departure for Leyden as a young professor, in January 1878.

The following letter from an older fellow-student at Leyden should be quoted here. The letter was written by Dr. G. J. Michaelis¹⁾ and was dated May 1st, 1929.

"I met him (Lorentz) again in Arnhem in 1873. He was filled at the time with new ideas about physics, and he suspected the existence of physical phenomena, unknown as yet, which he tried to discover. A primitive laboratory was established in his father's house, equipped with small instruments, partly made by himself, partly with the aid of Otto Lincker, instrument-maker and laboratory-assistant at the High School. Occasionally, on Sunday mornings, we would go to the little laboratory connected

¹⁾ Michaelis studied at Leyden where he received his doctorate in 1872. Till the end of his career he was a teacher at the High School in Arnhem.

with the High School, where van de Stadt was teaching at the time, and of which he later became headmaster. We did this without asking his permission, always taking care, however, that we left everything in proper order. Optical experiments were conducted mostly by means of my telescope. In a cover of the brass tube, which could be fitted around the lense, a round hole was drilled to let a thin beam of rays pass through. By this method refraction phenomena were studied. Lorentz was convinced of the existence of electromagnetic waves and tried to find out something about them by studying the discharges of a Leyden Jar. Sometimes he thought that he had discovered something, but the next day he would say that, whatever he had found could also be explained by the old theory. He did not succeed because of defective instruments¹).

Once I had promised to give a lecture before the Institute of Natural Science "Wessel Knoops", but I had not yet decided on the topic. Lorentz advised me to speak about the telephone. Fortunately Lincker had one, a rather primitive affair, but still I was able to telephone from one room to the other.

Once we received an invitation from a certain gentleman by the name of van Royen to inspect a model of a hot-air machine which he had constructed. He wanted, I believe, to apply for a patent on it in France. Lorentz then worked out a theory of the machine, which, as van Royen afterwards told me, evoked much admiration among the

¹) These experiments anticipated in an interesting manner the investigations of H. Hertz, who fifteen years later, in 1888, succeeded in proving experimentally the existence of electromagnetic vibrations originated by an electric discharge. Lorentz was convinced of this in 1873 already.

judges. It is pleasant to reflect that already then Lorentz encouraged others to do research. He would suggest them to try the solution of some mechanical problem by some method which in his opinion would lead to good results. During these pleasant gatherings, which took place in his house, Lorentz' father invariably was present. He used to take great pleasure in the proceedings. He was a jovial, friendly man, who later on conducted himself like a hero when his leg had to be amputated without the aid of anaesthetics.

At a social evening of the Wessel Knoops society, van Hogerlinden, the historian of the city of Arnhem, gave an account of the history of the society. To my great surprise he only casually mentioned the name of van de Stadt, who for years had been the very soul and centre of the group. In fact, without him the society would have been disbanded long ago. Van de Stadt was an eloquent speaker on the subject of popular physics. Master Timmer and he were Lorentz' teachers in physics at Arnhem. He often told me that he owed much of his love for physics to van de Stadt. When the latter relinquished his post as headmaster of the High School, Lorentz came over to address him. But he rated his humble teacher, Master Timmer, much higher. This man surely must have possessed a great talent as a teacher, and above all, the gift to encourage young people to self-study. Van de Stadt, to be sure, tried to do this as well, but during the years that Lorentz was a pupil at the High School he no longer needed such encouragement. Van de Stadt, moreover, lacked sufficient knowledge in the field of mathematics to be able to guide a budding genius".

In the course of his six years of teaching in Arnhem, Lorentz added to his own work by substituting in his

old High School for a teacher who had become ill. He did this for about one year. This seemed to cause him no difficulties, probably because his pupils there were more interested in the subject and also because of his own greater experience. As a teacher he was much appreciated and well liked. In June 1873 he passed his examination for the Doctor's degree, *summa cum laude*.

It was not without reason that the city of Arnhem honoured my father after his death as one of its greatest sons. He was born in this city, and his parents and grandparents had lived either there, or in Velp. It was, however, particularly the fact that Hendrik Antoon, except for a short study-period (September 1870 — February 1872), had lived in Arnhem until his appointment as Professor.

The years 1872–1878, passed in this peaceful little provincial town, presumably were happy ones for Lorentz. He was living again with his parents in the Steenstraat in quiet surroundings, only regretting that his brother (who afterwards was to become postmaster in Bussum) had left Arnhem.

Lorentz had left his friend Haga behind in Leyden, where the two had studied together for some months. Haga remained at the university until 1876 when he got his doctorate¹). Later he became assistant at Strasbourg, was teacher at the High School at Apeldoorn and at Delft (from which time dates his friendship with Kamerlingh Onnes); thereafter, in 1886, he was appointed Professor at Groningen. Haga was the first to demonstrate the diffraction of the Röntgen rays through a narrow opening, and to prove their undulatory character (1899); unfortunately this fact became little known.

¹) Thesis: "Over de absorptie van warmte door waterdamp".

In Arnhem, the friendly relations between Lorentz and van de Stadt became closer, and the companionship with the Henny family continued.

Lorentz' post at the evening school left him much time for private study, and my father therefore made no attempt to obtain a better position. He preferred to develop his talents quietly by himself, without outside aid or stimulants, which nowadays are so often used in helping young scientists. This uninterrupted self-study was essential to him, and the need for it undoubtedly explains his return to his native city. Everyone who came into contact with Lorentz, whatever his age, soon recognised this character trait. Only when he had thought out a problem by himself was he ready to discuss it with others and report his findings, but never for the sake of clarifying his own mind. And the same on another level: First quiet years of self-study and uninterrupted contemplation. Only when the first part of his work is completed, the outline of his life's work clearly drawn, does he withdraw from his retirement and enter the public sphere of scientific activity.

One of the most important instances in my father's student life was the fact that he became acquainted with the works of the great English physicist James Clerk Maxwell, the originator of the electromagnetic theory of light. Maxwell's first publications on this subject appeared in 1865. These and his subsequent publications were sent regularly to the Leyden laboratory of physics, where the 18-year old Lorentz was able to consult them. He took them home, read them and digested the new ideas, as his dissertation has proved. It was scarcely surprising that Lorentz was one of a few people only in the Netherlands who read and understood Maxwell's articles,

considering that during this period theoretical physics as a subject was hardly known in this country. Moreover, Maxwell's writings were hard to understand. Later on they were sometimes referred to as an "impenetrable intellectual jungle-forest"; Lorentz somewhere simply says: "It was not always easy to understand Maxwell's thoughts". How well he succeeded in this undertaking, and how much he contributed to the development of this theory in the course of his lifetime, is shown by Einstein's habit of speaking of the "Maxwell-Lorentz theory"¹).

Besides Maxwell's publications the works of Fresnel formed the most important part of my father's library. He had bought these early in his career and throughout his life continued to regard them as a priceless possession. In connection with this, I may quote a passage from Lorentz' speech delivered in 1927 on the occasion of the commemoration services of the centenary of Fresnel's death (1788-1827)²): "Pour ma part, je puis dire que Fresnel a été un des maîtres auxquels je dois le plus, et je me rappelle encore que lorsque, il y a plus d'un demi-siècle, mes ressources me permirent d'acheter un livre de physique un peu plus étendu que les manuels ordinaires, je me suis procuré la publication par Emile Verdet des Oeuvres complètes d'Augustin Fresnel. Lorsque j'eus lu l'Introduction de Verdet, mon admiration et mon respect s'étaient mêlés d'amour et d'affection; et quelles n'ont pas été les jouissances que j'ai eues, lorsque j'ai pu lire Fresnel lui-même et étudier ses beaux travaux, admirables par leur simplicité! Fresnel n'avait presque pas de laboratoire, souvent même il n'avait pas de laboratoire du tout,

¹) See e.g. A. Einstein, *Über die spezielle und allgemeine Relativitätstheorie*. Sammlung Vieweg 1920.

²) See page 149.

pour faire ses expériences. Vous savez comment, après le retour de Napoléon de l'île d'Elbe, il avait été interné dans le petit village de Mathieu, parce qu'il avait voulu résister à l'Empereur. Ce fut là que, avec la seule aide du forgeron, il construisit le micromètre avec lequel il sut déterminer la position des franges dans les phénomènes de diffraction, préparant ainsi sa grande théorie de ces phénomènes. Du reste, ses ressources mathématiques étaient aussi modestes que ses instruments d'observation. Fresnel n'était pas un mathématicien très exercé. Mais il a pu pourvoir à tout ce qui lui manquait par son génie et son intuition".

LAST YEARS IN ARNHEM

The award of his Doctor's degree, *summa cum laude*, was for Lorentz the culmination of three years assiduous labour. The young Doctor, who had gone to Leyden only for the sake of this ceremony, came back in Arnhem afterwards and continued his usual busy life. But apparently a change in the normal routine had come. In the summer of 1876 my father and van de Stadt, together with another friend, made a walking-tour through Switzerland which all of them enjoyed greatly.

During this time the question arose whether or not Lorentz should choose mathematics as his predominant interest and chief object of study. Haga used to tell how during their holiday excursions the two old friends would discuss this matter. In the end physics won. Nevertheless, how much Lorentz loved mathematics and how extremely capable he was also in this field was amply shown by the circumstance that in 1877 he was asked by the Faculty of Science at the University of Utrecht to become Professor in Mathematics.

In this same year my father applied for the position of teacher in physics at the Grammar School in Leyden. He was placed number one on the list, and the Professors at Leyden University promised to recommend him for the post of "private docent" in the University, if he would get appointed at the Grammar School.

At this time a new law governing Higher Education¹⁾ was introduced. As a result, a chair was created next to the one occupied by Professor Rijke. This led to a division of labour, one professor being appointed for the purpose of teaching experimental physics and the other theoretical physics. The original intention had been to offer the chair in theoretical physics to J. D. van der Waals. Van der Waals had obtained his Doctor's degree at Leyden in 1873, and had written a dissertation²⁾ of such merit that public attention had been fixed upon him at once. As a consequence of the new law on Higher Education, already mentioned, the Athenaeum Illustre in Amsterdam became a university in 1876. In 1877 van der Waals was appointed at this institution as the first and only Professor of Physics. As soon as it was certain that van der Waals would go to Amsterdam, H. A. Lorentz was appointed as Professor of Theoretical Physics at Leyden, in a new chair created for him. Thus he became the first Professor of Theoretical Physics in the Netherlands.

YOUNG PROFESSOR AT LEYDEN

On January 25th, 1878, Lorentz delivered his inaugural address, "Concerning the molecular theories in physics", and shortly afterwards his instruction began. One of the

1) Hoger Onderwijs.

2) "Over de continuïteit van den gas- en vloeistoestand".

first students in the new course was the future Dr. C. A. van Rijn van Alkemade, who in later years had a good deal to tell about those early days. He attended Lorentz' lectures from the first and retained throughout his life the neatly worked-out notes which he made at the time¹⁾. The first course of lectures was on the theory of capillarity by van der Waals. Lorentz gave in one of these lectures for the first time the derivation of the equation of state with the aid of the virial. Much later this lecture was published at the urgent request of Dr. Korteweg, Professor of Mathematics at Amsterdam²⁾. In another lecture the treatment of refraction phenomena was given with the aid of Fourier's theorem. Entirely original work, but this lecture was never published, not by Lorentz himself, nor, according to van Rijn van Alkemade, by anyone else. A few items are mentioned in the thesis of Thierry³⁾.

About ten students attended these lectures. Dr. van Rijn van Alkemade told me how my father, then 25 years old, possessed even at that time the remarkable gift of maintaining a certain distance between his students and himself, without appearing to do so; and this in spite of his kindness and simplicity. Van Rijn van Alkemade was 19 years old at the time and therefore but a few years younger than his professor.

Before the classes began they used to talk awhile, standing near the stove to warm themselves. Lorentz, on such an occasion, was quite apt to tease one of his students about something or other, without, however, being in the least disagreeable. Then he would look at

¹⁾ Due to a deplorable mistake these notes were destroyed immediately after the death of van Rijn van Alkemade.

²⁾ Wied. Ann. 17 (1881) 193.

³⁾ "Over de toepassing van het theorema van Fourier in de theorie der buigingsverschijnselen", 1900.

his watch and say: "What do you think, gentlemen, shouldn't we start?" After the lecture the young professor would join his students, van Rijn and the others, and, while talking with them, would walk along the Rapenburg to his rooms, which at the time were on the Turfmarkt, above a tobacconist. It was here that van Rijn van Alkemade often came to see Lorentz to talk about his dissertation. In particular he recollected one evening when he met E.A.O. Was, who, much later, was to write his thesis under Lorentz. They had a sociable evening together, discussed many subjects and ended up by drinking a glass of wine.

Van Rijn van Alkemade seems to have been very proud of his thesis, and with reason. As is generally known, many received their Doctor's degree under Lorentz, although their thesis was partly, if not entirely, the work of my father. This, however, was not the case with van Rijn van Alkemade. When the latter had finished his thesis, Lorentz remarked: "And this, Mr. van Rijn van Alkemade, is entirely your own work".

A typical incident occurred many years later. The thesis of one of the graduates — whose son told me this story—had been written with great difficulty, a considerable time after he had left Leyden University and had found a position elsewhere. Every two weeks he went back and forth to Leyden until he had finished the work, on which day the no longer young prospective Doctor returned home, his briefcase with the precious finished thesis tightly clutched under his arm. Probably because he seemed so happy and was so anxious about his briefcase, this precious possession was stolen from him. Then followed a desperate telegram to my father, who answered, also by telegram, that he himself would re-write the thesis.

The briefcase has never been found, but shortly afterwards the thesis arrived from Leyden.

During the first years of his professorship my father made many valuable contacts which were to last for his entire life. In 1872 F. Kaiser had died and his successor was H. G. van de Sande Bakhuyzen. This colleague, who was many years older, remained a trusted adviser and friend to my father until the end of his days. The younger brother of Bakhuyzen, Ernst, who later would become connected with the University Observatory also became his good friend.

In 1874 van Bemmelen was appointed Professor of Anorganic Chemistry at Leyden. His former pupil in Groningen, Heike Kamerlingh Onnes, and his present pupil in Leyden, Bakhuis Roozeboom, got acquainted with Lorentz through him. Kamerlingh Onnes, like my father, was born in 1853; he passed his final High School examination in 1869, his entrance examination to the university in 1870 and obtained his candidate's degree in Mathematics and Physics in 1871. He then studied at Heidelberg for a couple of years under Bunsen and Kirchhoff and started there the work for his thesis¹⁾ which he finished later on at Groningen. After obtaining his doctorate in 1878 he became assistant to Dr. J. Bosscha, the head of the Polytechnical School at Delft, and in 1882 he became the successor of Dr. L. Rijke as Professor of Experimental Physics at Leyden and thus Lorentz' closest colleague. The two young professors were friendly already in the time that Kamerlingh Onnes was at Delft. Both of them were soon received in the family circle of Bosscha. Bosscha had a great respect for Lorentz and never let a chance go by to give evidence of that fact.

¹⁾ "Nieuwe bewijzen voor de aswenteling der aarde", 1879.

Since his appointment in Leyden, my father thus lived in the midst of an interesting group of friends. He made also contacts outside of his professional circle. Several of his friends with whom he used to dine, still continued to visit our home in my youth. As to the sons of Professor Kaiser, then deceased, in their houses my father remained a welcome guest. One of these, inspector of government nautical instruments, lived in Leyden on a small estate, named Tusculum, which was situated on the country road which later became the Rijn- en Schiekade. It was there that in the summer of 1880 my father met the daughter of Professor Kaiser's brother. The latter, J. W. Kaiser, a well-known engraver, was Professor at the Academy of Fine Arts at Amsterdam and Director of the "Landmuseum van schilderijen enz.", at that time situated in the "Trippenhuis" on the Kloveniersburgwal¹⁾.

During that same summer the young, pretty Aletta Kaiser and my father became engaged. In consequence of this fact my father was introduced to a busy, happy family with eight children, four sons and four daughters, the eldest two of whom were already married. It is not surprising that at first he felt a bit awkward in the midst of such a lively group, so different from the family in whose midst he had grown up. But gradually he began to feel more at home. The stories told by Aletta's brothers,

¹⁾ The "Trippenhuis", a specimen of seventeenth century architecture, was built in 1660 by the architect Justus Vingboons (brother of the more famous architect Philip) commissioned by the brothers Trip, rich and influential merchants of Amsterdam. In 1814 both the "Koninklijke Akademie van Wetenschappen" (then and till 1851 named "Koninklijk Nederlandsch Instituut") and the "Landmuseum van Schilderijen enz." were housed in the "Trippenhuis". When in 1886 the latter moved to a new building (the present "Rijksmuseum") the "Koninklijke Akademie van Wetenschappen" (since 1938 named "Koninklijke Nederlandsche Akademie van Wetenschappen") remained the only occupant of the Trippenhuis.

how they met their new brother-in-law and became friends with him, furnish some of the most interesting commentaries on his personality. Cozy gatherings in Hendrik's room, first on the Turfmarkt, later on the Rapenburg, corner Doelensteeg, are mentioned. There they would find their new brother-in-law peacefully smoking his pipe, never making the impression of being engaged in strenuous work. And yet, my father must have worked hard and intensely during this time because there was much left for him to do. His thesis in a sense presented a well rounded whole, in so far as it showed conclusively that Maxwell's electromagnetic theory explained the characteristics of the reflection and the refraction of light better than any existing theory. On the other hand it stimulated to apply Maxwell's theory also to other phenomena. In fact, it opened to Lorentz a large field of applications. Many of these were made by him, to be later on confirmed by experiment. My father was so sure of his calculations that he never doubted the outcome of the experiments. Of this I may show a typical example. Much later, in the course of a conversation with other physicists, the talk led to the phenomenon of Kerr which was discovered in 1875. It appeared that my father had already arrived at the same result by means of his own calculations some time before he received his Doctor's degree. Why he had never published his results? "Since it is evident that all calculations would lead to this phenomenon, I might just as well have published many more results of my work".

FAMILY LIFE

Let me continue my story. We are still in the year 1880, and my parents had recently become engaged. The young

bride was radiantly happy, the new son-in-law felt at home in the house of the Kaiser family (then the "Trippen-huis"), and all members of his future relations-in-law increasingly appreciated him.

In 1881 the young couple were married. The wedding was a happy occasion which led to a good many festivities. All this was followed by a honeymoon-trip through the Schwarzwald. After their return my parents settled in a house on 60 Hooigracht, where on November 20th, 1885 their first daughter Geertruida Luberta would be born, the author of these pages. The child was named after her father's mother and stepmother. Half a year later my father bought the beautiful old house on 48 Hooigracht, where he would live during his entire stay at Leyden. After his death a memorial tablet bearing his name was affixed to the frontwall of the house.

Originally this house consisted of two identical houses, which fact is evidenced by the double step-gable. Each of these houses had a front and a back part, separated by a courtyard, and connected only by a long marble hall which led into the garden. Somewhere about the year 1800 these two houses had been joined together. On the right hand side of the building was a spacious suite of rooms with "witjes"¹⁾ above the doors and woodcarving and wallpaintings on canvas in the backroom. The back part of the left wing was taken down. That which is most important in my narrative is the remaining back part of the right wing. Here was found a large, square room. One entered it by climbing a flight of small steps, then through a door in the wall which ran parallel to the street.

¹⁾ Eighteenth century pictures in grisaille, mostly representing putti (cherubs) and found above doors. They derive their name from the wellknown painter of this genre, Jacob de Wit.



H. A. Lorentz and his young wife
± 1881





48 Hooigracht Leiden, where Lorentz lived from 1886-1912

Two windows with deep window-seats gave on the lovely spacious garden. On the left side was a shallow bookcase, filling the entire wall and leaving only room enough for a roll-top desk, standing near the window. My father's study.

How well I remember him sitting at his desk, putting his ideas down on paper in his well-known typical handwriting, easy, for he loved to write, clearly formulating his thoughts. At other times I found him seated in his easy chair, near the stove. In those days this did not mean a deep leather arm chair, far from it; it was a large folding chair, yet very comfortable. Sitting there, deeply immersed in thoughts, smoking his cigar, he was yet most ready for a chat or a joke with one of his children.

This quiet repose near the stove was often alternated with pacing to and fro in his room, which we used to call "ijsberen" (because it resembled the habit of polar bears who walk up and down their cages). For long periods of time one could hear his steady footsteps from the basement down below. Yes, this little stairway with its seven steps, leading to his room, how we children loved to play there with our dolls. Whether we were particularly quiet children or whether my father was never disturbed by the noise we made I do not know. In any case, we did not bother him in the least, for our mother would always take good care that my father was not disturbed while at work; in fact, she made this her life's task.

One other thing I remember in connection with the study was the row of portraits of physicists, which hung above my father's desk. I was so little at the time that I only understood that those portraits represented "very clever men". Naturally I often asked my father which one of them was the most clever, partly to see whether he

would be consistent in his answers. But he was. He invariably pointed at Fresnel ("from old times" he might say) and at the young Hertz. Later on my father told me more in detail about his admiration for Hertz, and much later, looking back and having a better understanding of the greatness of these two men, I felt it a curious thing that Lorentz and Hertz never met. Such a thing would be unthinkable nowadays, but even in those days it was unusual.

These are childhood-memories, but I hope that for those for whom these recollections have originally been written, they will aid to revive more clearly the image of my father's personality.

In later years the desk at which my father had worked so far was degraded to a cupboard, and replaced by a flat writing-table, which stood in the middle of the room. How many people, till the day of their death, will remember my father sitting and working at this table.

I go back to where I left off. After their marriage my parents continued to be the same happy couple which they had been before that time. Aletta, for whom the change from her busy parental home to a small family had been great indeed, adjusted herself very well. She devoted herself to her husband, who for his part tried to keep her informed about several of his activities. In about 1883, he was the first to arrange a physical laboratory for medical students. This took much of his time, since he was left to carry out this task with hardly any assistance. Often, in the evening, Aletta would accompany him and help him to arrange everything for the experiments for the next day, both for the laboratory and for the lectures. Through her dexterity, as well as her good judgment, she became a real help to her husband. Those evenings

spent together at the laboratory remained among their precious memories, all through their lives.

Besides this work Lorentz took upon him an unforeseen task. His friend, Kamerlingh Onnes, whose health was poor, was forced to take a long leave of absence in the year 1883. Lorentz then took over his course in general physics intended for future medical students; he gave two lectures a week. These lectures were also attended by first year students in mathematics and physics. After Kamerlingh Onnes had recuperated Lorentz continued with these lectures in order to ease the strain upon his colleague, whose health was still delicate. With this extra work he continued until 1906, when a third Professor of Physics, Dr. J. P. Kuenen, would take over this task. How much the medical students appreciated my father's lectures as well as the guidance and attention given to their laboratory work, and above all the personal interest he took in each one of them, was clearly shown when the fiftieth anniversary of his Doctorate was celebrated. Then, in recognition of his services, the medical faculty of the University of Leyden awarded him the degree of Doctor honoris causa; this was in 1925.

Also, apart from this extra work, his professorship as such demanded his close attention and a vast expenditure of energy, particularly because not only his colleagues, but many others relied on his judgment. So in the course of the years my father's time was far from being entirely spent in purely abstract speculation, although theoretical physics would remain the chief object of his attention throughout his entire career.

Lorentz spent the larger part of the day in his study, working. During the evening Aletta would always join him and keep him company. Perhaps among the women

who happen to read this biography there may be some who have had the same privilege of close association with their husband while he was working at his life's task. They will realise how much this must have meant to young Aletta. Not until the children were old enough to spend their evenings in the livingroom did my mother stay with them.

Thanks to the circle of friends which the Lorentz' soon gathered about them the serious evenings of study were occasionally alternated by gay parties at home. Aletta was a charming hostess, while my father was a sociable man and a pleasant conversationalist. Thus their life went on pleasantly, and was for my father rich in original work.

On April 29th, 1889, a second daughter was born, Johanna Wilhelmina, named after grandfather Kaiser. My sister and I had a happy childhood together.

Unfortunately, the happy family life of which I told, did not continue without interruption. In 1893 a son was born to my parents, but he died eleven months later, after a severe illness. The cares for this child and its death were a great trial to my parents, particularly to my mother. She did not have the serenity of mind which my father possessed. Nor had she, as few mothers do, an interest outside of her personal life which could make up for this lack. On March 8th, 1895, a second son was born, Rudolf, named after a brother of my mother. This little boy too needed a great deal of care during his first years.

In later years I have tried to visualize my mother's life during those years. My father found consolation and fulfilment in and through his work, and his wife was grateful that this was so. She heroically tried to keep her sorrows to herself, which added to the secludedness of her nature; a great strain for her nervous system.

Slowly life resumed its even tenure. My mother gave herself to her family with great devotion, and this not only in a material sense but in all respects. Her power of discovering new diversions which all could enjoy, seemed limitless. The help she had given to my father during the first years of their marriage now began to take on another form; it changed into efforts to ensure him the peace of mind which he needed for his work, and to take away from his shoulders all manner of drudgery.

As my parents lived very simply, they could afford, within certain limits, to render aid to needy families, of which there were a good many at that time. The large part of this work naturally fell to my mother, but my father on occasion gave his personal aid. A few examples of the way in which they would give help may serve; it will show that their assistance had both a sympathetic and a practical basis. Many years before Dr. E. Gorter, the famous Professor of Pediatrics at Leyden (he had been in private practice before) started a baby clinic, my mother each day prepared "soxlet" bottles with milk for a set of twins born in a needy family; she saved the lives of the children by doing so. When the eldest son of that same family left school at the age of thirteen, and had to start work in a factory in order to earn some money, my father made it possible for him to learn the trade of mason instead, which was what the boy had always wanted to do. But my father did more than that. At that time a poor apprentice to a bricklayer became a foreman, that is a helpmate mason, once his apprenticeship was ended, but he could not rise any higher; to become a mason remained out of his reach. Because my father kept in constant touch with the boy's boss and interested himself in his progress, Teunis, which was the boy's name, was

able to skip the position of foreman and he became a clever master-mason. Teunis, in his older days, showed his gratitude to our children by helping them in the difficult years of the second world war.

My father regularly spent some of his precious time with us children. With the little ones he played games. Me, he taught the first problems of arithmetic, and, what he seemed to consider even more important, the art of writing plainly the figures. When we went out he taught my sister and myself how to read a map, and how to find our way when walking through the woods. During those excursions we soon learned the names of the wild flowers, always the Latin names, so that when I was ten years old I already knew how to determine and classify several plants. A few years later he helped me to read Julius Caesar, after I had tried my own hand at it without any aid at all.

Thus far my own childhood memories. I do not wish to continue these however, for they would present but a limited picture of my father, interesting in itself, but scarcely all-embracing. And yet it is worthwhile to point to the fact that he excelled as a father and faithful husband, that he was always cheerful in the circle of his friends and his family and often gay with his children. Thus he remained throughout his lifetime, although increasing age tempered his gaiety to cheerfulness. Once he had created himself his place in the family, his relationship to his wife and his children, nothing on earth could ever induce him to change any of these. This was the reason why my father's essential attitude towards life was not affected by the events which happened within the domestic circle. Therefore I shall only mention some of the more important happenings within our family group.

In the first place let me say that we children owe a debt of deep gratitude towards our father for his constant devotion and true love, and for his disregard of all difficulties whenever he felt the necessity of his assistance. This same gratitude was felt by all our relatives who had become closely connected with him; each of them had some reason to be grateful to him. Thus, for instance my mother's parents. After becoming emeritus in 1883, old Professor Kaiser and his wife, Johanna Buisman from Zwolle, moved to a small estate, Zuidwijk¹⁾, on the road, leading from the Haagsche Schouw to The Hague. Afterwards they moved to Leyden, where they died respectively in 1900 and 1907. Throughout all these years it was an exception when their son-in-law Hendrik did not pay them his regular weekly visit. My grandfather in particular counted on those visits. After his retirement he had turned away entirely from the Arts and devoted himself mostly to the reading of historical works and of books on natural science; these Hendrik procured for him from the University Library. Afterwards, when a heart ailment confined my grandfather to his chair, he occupied himself entirely with these studies.

For all of these people mentioned, and particularly for us, his children, it is an invaluable privilege to have been in such close contact with this great man. This privilege was enjoyed by an increasing number of people, when my father's contacts with the outside world became more numerous. To know him meant to appreciate and to love him.

¹⁾ The house is still there, modernised for the larger part. The stone pillars at the entrance are still to be found. To visit them, my parents had always to walk all the way from the Hooigracht, Leyden, to Zuidwijk.

THE SCIENTIFIC WORK

BY

A. D. FOKKER

I. THE THEORY OF ELECTRONS

The dissertation. Lorentz began his life's work with the writing of a masterly dissertation "On the reflection and refraction of light". This Doctor's thesis was publicly defended at Leyden on December 11th, 1875. Beginning with a critical investigation of Fresnel's theory of light, it ushered in Maxwell's electromagnetic theory of light.

The very first germ of this theory is found in the discovery of the Danish astronomer Olaf Römer. From the systematical accelerations and retardations of the eclipses of one of Jupiter's satellites Römer inferred that light needs a certain amount of time to reach the earth. This discovery he communicated to the "Académie des Sciences" at Paris in 1675. Christiaan Huygens took a starting point here and in 1678, in his "Traité de la Lumière" tried to give an explanation of this propagation of light by means of an illustration. Anyone who ever touched the surface of water will have observed that circular waves spread out from the point where he touched the water. Huygens imagined that the propagation of light was similar to the spread of sound waves in air. He used the

term wave here in a metaphorical sense, borrowing it from the observation of the phenomenon already referred to in connection with touching a water surface. But, whereas in the water the ripples form concentric circles, the sound waves form spherical regions where the air has become condensed, alternating with concentric regions where the air has become rarefied to a certain degree. This succession of condensations and rarefactions shifts its position: the spheres become larger without any displacement of the air particles except for a slight vibration. Thus the propagation of sound is explained. In much the same manner, Huygens argued, waves spread out in ever growing spheres from a luminous centre.

No air is found in interstellar space and in the space between the planets. Huygens' theory of the propagation of light implies the existence of a carrier of waves: matter which can be made to move in wave-like fashion. It is obviously necessary that one first believes that such matter exists. Huygens was forced to assume that there was an ether everywhere between the planets and the stars at points where all earthly matter was reduced to nothingness. Huygens conceived the idea of an extremely rarefied gas existing of very fine particles, loose globules, which would fill universal space almost entirely with the exception of small interstices.

Huygens' theory was not accepted during his lifetime. The theory of Newton was generally adopted, which derived from the notion that light consisted of particles which reached us from the sources of light. It was not until the beginning of the nineteenth century that physicists abandoned this purely material explanation of the propagation of light and returned to Huygens' theory. The so-called interference experiments by Young and

Fresnel taught that light could be described in terms of alternating plusses and minusses, or in other words, as a vibration. This led to a better understanding of diffraction experiments too. It gave, for instance, the reason why there is a luminous point in the centre of a shadow of a perfectly round opaque disk. It is noteworthy that several of these experiments, which confirmed Huygens' theory, were already known during Huygens' and Newton's days, but an adequate interpretation was lacking then.

Huygens visualized the ether as a gas with mobile particles. However, he himself did certain experiments, for which he even gave a theoretical interpretation, which were inconsistent with this theory. He had given much consideration to crystals of Iceland spar, and he had made several measurements on them. These crystals have the curious property of doubling the light beams passing through them. The result is that when looking through a crystal one sees the objects beneath it double. Huygens' theoretical analysis is admirable. It led him to the conclusion that matter such as Iceland spar (calcite) allows the transmission of two kinds of waves, the ordinary spherical waves and the extraordinary ellipsoidally flattened waves.

Whence this duplication? The concept of a gas or a liquid offers no possibilities for the explanation of this phenomenon. It allows only waves similar to sound waves, in which the direction of the vibration of the particles coincides with the direction of propagation of the waves along the ray. It was Augustin Fresnel who in 1821 had the courage to break away from the then prevailing notion of longitudinal waves. He believed in the idea that the vibrations of the ether did not occur in the same direction as the light ray, but in a direction perpendicular to it.

The vibrations propagated in the waves had to be transverse, two mutually perpendicular vibrations. Much courage was needed to publish this idea and to adhere to it in spite of the difficult consequences which it entailed. For if vibrations are transverse it follows that there are no compressions and rarefactions in the ether, but twistings, distortions: "shears" as they are called. Since the ether, in view of the propagation of such shears, is able to resist them elastically, it must not then be called gaseous but should be considered to possess the elastic qualities of a solid body, which, in contrast to liquids, opposes changes of form.

The ether a solid body! But how then is it possible that material bodies move through it, why are they not solidly fixed in it? Undaunted and without any mental reservation Fresnel decided that the ether is able to penetrate all bodies freely and without hindrance. More accurately, the ether allows all bodies unimpeded to pass through it in spite of the fact that it is solid itself. In matter which is optically more dense, with an index of refraction greater than one, Fresnel says the ether should have a greater density. If a piece of glass is moved, virgin ether, so to speak, enters the front part to replace the ether which leaves the glass at the rear. To the extent to which the ether inside of the glass has a greater density than the ether without, it follows the motion of the glass according to a certain dragging coefficient. No greater degree of mobility than that, Fresnel believes, may be accorded to ether. We shall reconsider this matter later on.

But a second objection against the hypothesis of the existence of a solid, yet elastic, ether Fresnel could not remove, nor in fact could this be done by those who followed him and further developed the theory of vibra-

tions in an elastic medium, Cauchy and Neumann. From whatever angle one looks at this problem, the fact remains that in an elastic medium in which transverse vibrations are propagated, longitudinal vibrations should be able to develop as well; this is inevitable. Such longitudinal waves, however, have never been found. This obstacle ultimately rendered untenable the theory that ether is an elastic medium. In this respect only the hypothesis presented by James Clerk Maxwell could unlock a way out. Maxwell explained light in terms of very fast electromagnetic vibrations. This brings us back to Lorentz' dissertation.

Not only did the beautiful theories concerning an elastic ether utterly fail to explain why there is no light showing longitudinal vibrations, there was another difficulty. The rules which determine the strength of the fraction reflected by an interface when light passes from one medium to another, formulae carefully laid down by Fresnel and confirmed by observations, cannot be explained by the elastic light theory. Lorentz carefully analysed these deficiencies and put them into full daylight.

The more Lorentz became aware of the shortcomings of the old theory, the greater must have been his satisfaction in being able to show in the following chapters, after an exposition of the basic principles of Maxwell's theory, how the electromagnetic theory of light explained why there are no longitudinal vibrations, and was able to account naturally and fully for Fresnel's formulae for the intensity of the reflection. In cases when the light's angle of incidence inside the glass is too large, it cannot pass out into the air; it is totally reflected. This means that it is reflected without loss of intensity. Nevertheless a certain motion of light, like a narrow fading fringe in the air alongside of the glass, accompanies the total reflec-

tion and hems it in. Should one insert in this fringe a second piece of glass, without making contact with the first one, light would penetrate into this second piece and the total reflection would be disturbed, as was shown in an experiment already known to Newton. The details of this hemming in of the light are fully treated in the dissertation.

Lorentz goes further and deals with the theory of the reflection of light from metals, which corresponds in many respects to the previous investigation of total reflection. Lorentz obtained all these results himself. In the introduction to his dissertation he says that a remark made by Helmholtz, who apparently had come to some conclusions regarding this matter, had been the incentive for the work he had undertaken, but that he had seen only this short remark and nothing more. And at the end of his thesis Lorentz reaches the conclusion that Maxwell's hypothesis must have priority of the former undulation theory.

With regard to future possibilities Lorentz continues:

“The other light phenomena too, when considered in connection with this hypothesis promises to add a great deal to our present knowledge. One need but point to such matters as the chromatic dispersion, the rotation of the plane of polarisation and the connections of these effects with molecular structure. In addition there is the problem of the mechanical forces which may develop in connection with light phenomena and of the influence, which external forces or the motion of the medium, may exercise. Finally there is the emission and absorption of light and radiant heat.

With regard to the latter an important corollary from Maxwell's theory presents itself. If it is true that light and radiant heat consist of electric vibrations, it is natural to suppose that in the molecules of the bodies, which generate these vibrations in the surrounding medium, electrical movements also take place which increase in intensity with the increase in temperature. This idea, which is not new but which derives a high degree of probability above all from the electro-magnetic theory of light, seems to me to be a most fertile one. Perhaps in the theory of heat one may expect not insignificant results from the consideration of those electrical movements, especially in view of the energy of the motions which take place in molecules, the exact amount of which so far has given rise to great difficulties. As far as the theory of electricity is concerned, the idea just mentioned could lead to an explanation of the heat production by electrical currents, of the thermo-currents and related phenomena. Finally, the theory of light should show how the electrical motions in question are related to the physical and chemical condition of matter, a relation underlying spectral analysis, which is so rich in startling results.

Indeed, far from having reached a definite form, Maxwell's theory still demands further elucidation of matters, the explanation of which cannot be given, or if at all, only in rough outlines. But one of the advantages to be obtained from every extension of our knowledge of nature lies just in its putting clearly before our eyes what still remains to be done, and in its indicating the directions we should take for fruitful further research".

This is surely an impressive programme, unfolded in the last page of Lorentz' dissertation. It is interesting to state how many of Lorentz' later studies prove to be the working-out of ideas here touched upon as a dawning of prophetic intuition.

Further developments of Maxwell's theory. Lorentz later on will infuse into Maxwell's theory an atomic conception of electricity. Everywhere in the interior of matter he sees charged particles acting, and he makes a sharp distinction between those material particles and the ether. It is not possible, neither is it my intention, to picture in this sketch the gradual development of Lorentz' axioms, the clarification and increasing precision of his formulations. In his dissertation his theory has not yet fully outgrown some ideas derived from Helmholtz, although these ideas have no bearing on the chapters dealing with light.

Maxwell's writings were obscure and mysterious. For the generation which had to digest them the treatise on electricity and magnetism came to be, to quote Ehrenfest, a kind of intellectual jungle, all but impenetrable in its untamed fertility. Lorentz himself states: "It is not always easy to comprehend Maxwell's ideas. One feels a lack of unity in his book due to the fact that it records faithfully his gradual transition from old to new ideas" (Collected Papers VIII, 356). Lorentz, Heinrich Hertz and Oliver Heaviside are the main elaborators of Maxwell's scientific inheritance. Lorentz here opens up great vistas. Whereas Maxwell's calculations still rest on the premise that ether in empty space and ether in glass are two continua with distinct properties, for Lorentz the ether is the same everywhere. If the observed phenomena, taking place in both media, appear to be dissimilar, this must be due to

the fact that, besides ether, matter also is involved, and actually it furnishes a proof for this assumption. Hertz accepts the hypothesis that the ether may move together with the matter, i.e. the ponderable matter, in which it is found. Lorentz takes it that the ether is absolutely at rest, and he will stick to this axiom even more firmly than Fresnel who admitted some dragging of elastic ether by moving matter.

The separation of ether and matter. The simple basic idea, the great conception, which distinguishes so characteristically Lorentz' theory from all others, and which caused it to outlive all of them, is the fundamental and total separation of ether and matter, i.e. of the imponderable ether and the ponderable matter. On the one hand Fresnel's idea, that ether can penetrate freely all material substances, is thus affirmed. But, on the other hand a denial is implied of Fresnel's and Neumann's hypotheses to the effect that in various substances the characteristics of ether differ, for Fresnel in its density, for Neumann in its elasticity.

An important notion in Maxwell's theory is that of the dielectric displacement. This word fits the illustration used in the elementary explanation of the theory and is employed to show the origin and the existence of a particular condition in which ether may find itself. One pictures ether as consisting of two parts, one of which, an incompressible liquid, vid. electricity, is tied elastically to the other and is capable of motion. If a small ball is positively charged, the surrounding liquid is pushed aside and the ether takes on a condition of strain. If a small ball receives a negative charge a suction of the liquid occurs and again a condition of strain in the ether arises. In

principle Maxwell does not make a distinction between the dielectric displacement in the ether and in a medium, say, in a piece of glass. Lorentz, in his basic theory, implies that there is a real difference between the two, because in the glass, when brought in close proximity to objects that are charged electrically, displacements of small charged particles will take place.

The dielectric displacement in the ether meant for Maxwell an actual displacement of electricity. In Lorentz' mind too, changes in dielectric displacement amount to electric currents. But Lorentz places alongside of, and in opposition to those, so to speak, intangible, immaterial currents of hypothetical electricity, bound to a position of equilibrium, convective currents in which the charge is carried by material particles. Ether is found everywhere between the molecules and the atoms, which consist of charged particles; it is found even within those particles. This ether is in no sense affected by common matter, which carries no charge. Only electrically charged matter has an effect on ether, and in turn ether can exert a force only on charged matter. The way of charged matter, when acting on ether, is not putting it into motion, or compressing it, or something like that, but rather causing it to take on that particular condition which we term "electric field" or "magnetic field". Only when it is in this condition can ether act on charged matter. If there is no electric or magnetic field the ether does not act on matter.

This train of thought implies that electric particles cannot directly influence each other. On the contrary, an electric particle can react on ether only when, as previously stated, it brings about a dielectric displacement. This dielectric displacement is transmitted in the ether.

If, on account of this, the ether at a distant spot is brought into a condition which we term electric field, it may affect at that point another charge. The possibility of a direct immediate effect at a distance of one electric charge on another, — still a factor in Helmholtz' theory —, is hereby denied and completely replaced by the notion of transmission of the effect by an intervening field.

All these concepts are so commonplace to-day that they seem self-evident. It is even difficult to go back in imagination to a status of physical theory preceding the time when a sharp formulation of the stated underlying principle was given. To many who acquainted themselves with these principles it seemed as if a fog had been lifted from before their eyes.

Let us in the next section consider another consequence of Lorentz' axiom.

The Lorentz force. If an electric current passes through a conducting wire a magnetic field is created in its vicinity. Let us suppose that the current in a wire runs from East to West, and that we bring the prongs of a horseshoe magnet near to it, the North pole on the North side, the South pole on the South side of the wire, then — and this is Ørsted's discovery — the magnet will be forced down by the wire, and the wire will be raised by the magnet. Not so, says Lorentz' axiom. This is not the case. The magnet can only be acted upon by the ether and not by the wire carrying the electric current. The wire can react solely on the ether, and only if electric charges are present. Therefore, the wire carrying the current, though not charged, still contains charged particles, both positive and negative, and that in equal number. It is clear that the charges of the electric current are in motion. The

charges will cancel one another; the ether is not excited into the state of electric field, but the motion of the charges will change the ether into a magnetic field. In this condition it acts upon the magnet. Therefore the magnet too must contain charged particles, for otherwise the ether could not act upon it. Well, the hypothesis that a magnet is filled with small electric circular currents had already been made by Ampère. How electrically charged particles can be affected by forces, when placed in a magnetic, and non-electric field, is a matter still to be settled.

In order to examine this matter we follow Lorentz in observing the force to which the wire mentioned above is subjected in the magnetic field between the poles of the horseshoe magnet. It is forced upward if the current runs from East to West, which means that the charged particles which move within the wire are being pushed upward by the ether. They may be positively charged particles running Westward. But it appeared later that one had better consider them as negative particles moving Eastward between fixed positive particles, than the other way round. These negative particles in a conducting metal wire have since received the name of electrons. With Lorentz we arrive at the conclusion that such an electron is affected by forces if in motion within a magnetic field.

This is an extraordinary phenomenon: an electric particle which has nothing magnetic about it, will nevertheless when present in a magnetic field, yield to a transverse force exerted by the ether. This force should be directed perpendicular to both the velocity and to the direction of the magnetic field, and be proportional to the area of a parallelogram which can be drawn with the velocity and the field as sides.

This conclusion was added by Lorentz to the basic

theorems of the theory, after he had elaborated these with greater precision. The theorem mentioned presents itself immediately to explain a phenomenon of another kind connected with the electric dynamo. It is the phenomenon of a wire carried past a magnet, in which there is an electric force which we call the induced electromotive force. In fact, one only need to remember in this connection the charged particles, the fixed positive ions and the movable negative electrons which are present in the conductor and which share in its motion in the magnetic field. These will be subjected to the forces which e.g. will push the ions to the right and the electrons to the left side. But the ions are fixed in the wire, whereas the electrons may yield to the force affecting them. Whenever they do so it means that an electric current has been set up, the origin of which may be freely and easily understood from that other effect, namely the force exerted by a magnet upon a fixed conductor carrying a current.

Chromatic dispersion. We cannot here undertake an ample account of how Lorentz step by step arrived at the simplification and the more rigorous definition of Maxwell's basic principles. I imagine that in the course of his lecturing on these matters, ever and ever again expounding and explaining them, each time their character was more and more clearly revealed. In his papers he laid down his acquired deeper insights. His first publications contained an elaboration of the electromagnetic theory regarding phenomena which had previously been treated by means of the elastic theory of light. We are concerned here with chromatic dispersion by which is understood the relation between the index of refraction and the frequency, as well as the link between the index of re-

fraction of a given material and the density which it presents in a particular condition (hot, cold, gaseous or liquid). Chromatic dispersion is explained by a study of the particles within matter which are tied elastically to their equilibrium positions and which may vibrate with the motion of the light. Depending upon whether the frequency is farther removed from or closer to the natural frequency of vibration of these particles, in view of their mass and their elastic binding, these particles will take part in the vibration to a lesser or higher degree, and in turn react less or more upon the motion of the light which induced their vibration, and in consequence cause the velocity of propagation of the waves to be dependent on the frequency of the vibration.

In Lorentz' opinion these particles must be viewed as electric particles which are shaken about by the electrical waves of the ether. In turn they will emit electrical waves which must affect the neighbouring particles and further surroundings. This influence on neighbours becomes stronger according to the closeness of their proximity. This is the reason for the dependence of the velocity of wave propagation in any given material substance on the frequency of the vibrations and on its density. The papers in which Lorentz develops these theories are circumstantial, they are interesting, but the fact remains that others had reached the same results without the aid of the electromagnetic theory of light.

Rotation of the plane of polarisation. The concluding remark of the preceding section does not apply to the explanation of the rotation of the plane of polarisation of light which passes either through a piece of glass or some other ponderable medium in a direction parallel to an

existing magnetic field. Here the basic assumptions advanced by Lorentz should be applied regarding the influence exerted by the ether through its magnetic field upon a moving charge.

In beams of rectilinear polarised light, there is a plane containing the line of vibration and the ray of light. A linear vibration may be taken to consist of two circular motions running in opposite directions, one turning towards the right, the other towards the left. These circular motions meet one another at the end of a diameter in the aforementioned plane containing the line of vibration and the light beam. If the light beam should have traversed a medium in which one of the circular movements moves faster than the other, the meetingplace will be at the extreme end of another diameter, slightly turned with respect to the former diameter, and therefore, in another plane. The combination of the two circular motions produces a rectilinear vibration in a new direction. It is then that we say that the polarisation plane has rotated. If we are able to see why righthanded circular polarised vibrations and lefthanded circular polarised vibrations move with a different velocity, we are able to understand the rotation of the plane of polarisation during the propagation of rectilinear polarised light.

In the case of circular polarised light the charged particles in the glass will move in circular orbits around a centre given by their position of stable equilibrium. Let us take for the sake of our argument that a beam of light moves in a downward direction. Let us suppose that it has entered through a hole in the Northpole of a horseshoe magnet, and after passing through a glass plate leaves through a hole in the Southpole of the magnet. Thus the light beam runs parallel to the direction of the magnetic field.

The particles moving in their circular orbits will then, according to Lorentz' formula, be subject to a force in the magnetic field of the ether which acts perpendicular to this field as well as perpendicular to the light beam. This force is therefore directed towards the centre of the orbit in which these particles move, or away from the centre, depending on whether they are charged positively or negatively, and on whether they are turning to the right or to the left. This force therefore increases or decreases the centrifugal force which must be neutralised by the binding elastic force. Supposing the circulating particles to be negatively charged one might say that the binding elastic force seems to increase or to decrease depending on whether they are turning left or right. This means that the frequency of the vibration of the particle is higher for a righthanded circular motion than for a left handed one. We already know from the theory of dispersion that the velocity of the propagation of light depends on the difference of frequency of the light waves and of the proper vibrations of the particles. The velocity of light therefore will be different for righthanded and lefthanded polarised light, and this is what causes the rotation of the plane of polarisation. This rotation of the plane of polarisation in a magnetic field was discovered by Faraday; Lorentz presents us with the explanation.

The Zeeman effect. Another effect, sought by Faraday already in 1862, was the influence of a magnetic field on the emitted light, when the field was turned on the source of light. Spectroscopy in Faraday's time was not sufficiently developed and he could not detect the effect which he believed to exist. In 1896 P. Zeeman at Leyden succeeded with the help of a Rowland grating to discover

a broadening of the spectral lines of sodium vapour, both in emission and in absorption, whenever a magnetic field was actuated. The explanation is found in Lorentz' theory to which we made reference. We have already seen that in the case of a vibrating electric particle the lefthand and righthand circular motions, perpendicular to the direction of the magnetic field, will show a frequency different from an undisturbed vibration. The rectilinear vibration parallel to the magnetic field does not, however, suffer any change because a charge in a magnetic field is influenced only when its velocity has a component perpendicular to the field. Thus the proper frequency of an elastically bound vibrating electric particle is split into three parts. Lorentz immediately could tell Zeeman that the rims of the broadened spectral lines which he saw in the light which was emitted along the magnetic lines of force should show circular polarisation. Zeeman verified that this in fact was the case, and it was possible to deduce from the direction of the circular polarisation which he detected, that the electric particles vibrating in sodium atoms were charged negatively. This was a most beautiful discovery. A mass of new discoveries resulted. An analysis of the theories bearing upon this matter was offered by Lorentz to the congress at Paris in 1900.

EXPERIMENTAL CONFIRMATION

The action of convection currents. It goes without saying that it was exceedingly important to test experimentally the fundamental principles of the theory of electrons laid down by Lorentz. In the first place, experimental confirmation is needed for the thesis that the motion of an electric charge, that is a convection current, has the same

effect, i.e. operates in the same way upon magnets, as does a galvanic current. The difficulty to show this lies in the fact that, if one causes electrostatic charges to be set in motion, the strength of the current in electromagnetic measure is so very small. This means that the forces exerted upon magnets are very small indeed. Nevertheless, these tests have succeeded, Rowland, Röntgen and Eichenwald have confirmed the fundamental theory.

The immovable ether. Still another experiment was needed to confirm those propositions in Lorentz' theory which differed from those accepted by others, the sharp demarcation as we have called it between the parts played by ponderable matter and by the ether. In order to understand this experiment we have to draw heavily upon our imagination. If we take two conducting plates facing and parallel to each other and apply an electric tension to them, then the sides facing each other are charged, the one positively, the other negatively. Between the boundary plates there is a dielectric displacement everywhere. Through each geometrical plane which we insert parallel to the plates, the dielectric displacement is the same. Should we insert between them a parallel thick flat metal plate, then in this plate too the displacement would be of the same magnitude. On the one side the intervening plate would be charged negatively, on the other side positively, and it would show the same surface density of charge that is found on the boundary plates. In the interior of the plate there would be no electric field. Should we replace the metal plate by one made of ebonite, of equal thickness, or some other nonconductor, also parallel to the boundary plates, then the dielectric displacement within the plate will be as great as that

outside of it. Within the plate the particles of ebonite by their material displacement will add to the electric displacement. The dielectric displacement in the ether within the plate therefore becomes smaller than outside of it, but it does not completely disappear as was the case in the above mentioned metal plate. The consequence is that the material electric displacement by the charged ebonite particles will appear on the surface of the ebonite plate as a charge which has less density than the one found on the surface of the conducting plate. The difference in the density of the charge is coupled to the dielectric displacement in the ether between the ebonite molecules. The experiment conducted by Eichenwald was as follows: He set in rotation first the metal plate and after that the ebonite one, then compared the magnetic action resulting from the motion of the surface charges. If Hertz had been correct in his assumption that within the ebonite the ether participated in the motion, the effect would have been the same in both instances because the charge on the surfaces of the ebonite plate which corresponds to the dielectric displacement in the ether should move too. The result of the experiment taught Eichenwald that this is not the case; only the charged material atoms of ebonite are capable of motion and through their charge, may exert a magnetic influence. The ether does not move¹). This confirmed Lorentz' theory experimentally.

II. STATISTICS

Kinetic theories. Up to this point we have limited our attention to Lorentz' dissertation and the work which

¹) In order to facilitate the experiment, Eichenwald coated his insulator disc with thin metal foil on both sides. Whenever he put the coatings in electrical contact, the disc functioned as though it were a metal plate; when he isolated them, the disc functioned as an insulator.

resulted from this. But we have disregarded another field of interest in which he has been active. This field is indicated by the title of the address which he gave on the occasion of his inauguration as Professor at Leyden, on January 25th, 1878. He was then 24 years old. The subject of his address was the molecular theories in physics. The kinetic theory of gases, which, after Clausius, had been more firmly established by Maxwell, had reached its most complete treatment in the hands of Boltzmann. Evidently a strong stimulation had resulted from van der Waals' famous thesis, defended at Leyden some years before. To this Lorentz added his profound conviction that a deeper understanding of numerous phenomena could only result from a more thorough comprehension of the mechanism of atoms and molecules.

Lorentz' first treatise dealing with this matter furnished an accurate analysis of the details of an intricate problem. The difficulties involved had presented the opponents of the molecular theory with arguments to substantiate the claim that this theory did not explain the very things which it might be expected to explain. The special matter of discussion was the propagation of sound through air. Lorentz prepares the discussion of this problem by establishing an equation equivalent to the one upon which Boltzmann's theory rests, and then everything comes to light that had lain hidden only in hints of Maxwell regarding the propagation of sound. Yes, in his paper of 1880 Lorentz is ahead of his time. During the rapid compressions and expansions in the sound waves, the temperature of the air particles changes because the impacts accelerate the speed of the molecules for a moment, while immediately thereafter they lose their velocity. If the gas molecules consist of more than one atom, vibrations

within the molecules are also possible and a stationary equilibrium must result between the average energy of these inner molecular vibrations and the average energy of the translatory movement. During the variations of the latter in the sound waves the inner energy must readjust itself to these changes through energy exchanges. This readjustment takes place very rapidly, it is true, but it does take some time. Lorentz in 1880 clearly saw that if the vibrations in the sound waves should occur very rapidly, the possibility did exist that not enough time would be left for the readjustment of the inner energy to the energy of translation. In that case the inner motions would so-to-speak be eliminated and the result would be a change in the velocity of propagation of sound. In the eighteen eighties no experimental possibility existed to produce such very rapid vibrations, but fifty years later the situation changed. In the case of ultrasonic waves the effect indicated by Lorentz has in fact been discovered.

In the same year, 1880, Lorentz publishes a short, but fundamental paper in connection with a criticism raised by Maxwell in a review of the thesis of van der Waals containing the well known equation of state. Maxwell claimed that he had obtained a different result. To test this claim Lorentz improves upon the accuracy of the method, and shows that by so doing one reaches in fact the results published by van der Waals.

And thus it happens time and again, in all matters of detail Lorentz proves to be the incomparable master who turns all things into the right track. Thus we see it when he, led by a question put to him by Kamerlingh Onnes, concludes that Boltzmann, in his original proof of his famous so-called H-theorem, had made an omission. Again

he straightens this out, and in a publication in the year 1887 he adds the complementary facts which Boltzmann's argument needed. Boltzmann at once agrees with Lorentz and the result of this discussion is the proof for Boltzmann's theorem in the form that now belongs to classical tradition.

But it is not only a matter of clearly understanding the fundamental principles. With his kinetic theory Lorentz sheds light upon everything. He applies his molecular theory for the purpose of explaining the well-known laws of the reduction of the vapour tension above diluted solutions, of the decrease of the freezing point and of the osmotic pressure.

Entropy and thermodynamics. The molecular theories present the explanation of the second law of the mechanical theory of heat and of that powerful central conception of thermodynamics, the entropy. Through the capricious random collisions of the gas molecules the entropy can only increase and never decrease, because chaos offers the greatest chance of realisation, the greatest probability. The grand concept of entropy, that all-ruling quantity, so enigmatic for the beginner; to see it as an expression for the probability, thus reformatting a doctrine of random chances into that unyielding law of nature: the second law of thermodynamics, to this vision, to the chiseling of this mental creation Lorentz has contributed with all his strength. He recognized the importance not only of the way in which Boltzmann had tackled this problem, but also the fundamental importance of the work by Willard Gibbs. He explained these matters in a manner that opened the eyes of others to the importance of these statistical methods of canonical and microcanonical ensembles, if I may be forgiven the use of these technical terms.

The investigation of the field of thermodynamics was on the whole completed when Lorentz began his work; he had not participated in the fundamental creation of this subject. But the explanation of the basic facts of thermodynamics in his lectures, and later, in the collection of his "Abhandlungen über theoretische Physik" belong to the best that has ever been published about this matter. In 1886 we find him engaged in the development of the thermodynamic theory as applied to thermoelectric phenomena in metals to which he later returned repeatedly in his theory of electrons, but then from the angle of the molecular-kinetic theories.

The theory of radiation. The striking applications of thermodynamics by Boltzmann and Wien to obtain fundamental results regarding intensity and structure of temperature radiation were an inspiration to Lorentz to deal with those theories in terms of electromagnetism (1901). If a number of bodies are enclosed within a given space without touching each other, they will, due to radiation, arrive at a condition in which all of them will have the same temperature. They are in a state of stationary equilibrium, not directly because action at a distance does not exist, but through the ether. The ether is filled with radiation energy, that is to say, with irregularly changing electromagnetic fields which affect the bodies and increase their temperature, or which may in fact originate within the bodies themselves, in consequence of which they lose heat. To each temperature a definite radiation field in the ether corresponds which has a given intensity and colour, or more accurately, a radiation field which in each colour shows a given intensity. The great problem was to understand how the distribution of energy in the spectrum

depends upon the temperature. Through a formal application of the methods of statistical mechanics to the vibration of a part of the ether enclosed between mirrors, Jeans found a formula which only in part corresponded to observed reality. In the same sense in which Wien's formula fits conditions at low temperatures and at the ultraviolet side of the spectrum, Jeans' formula fits conditions at high temperatures and at the infrared side of the spectrum. Planck's formula would later succeed in reconciling both theories at a higher level of unity, and bring them in correct relation to the actual measurements.

Lorentz endeavours to find a way to discovering a direct relation between the random thermal motion of his electric particles and the distribution of energy in the spectrum, by considering both the absorption and the emission. In this connection he studies the gases and he publishes his classical explanation, to the effect that gas atoms take in energy from radiation of precisely the same colour which they themselves are capable of emitting. Through collisions this energy is changed into heat. He then studies metals and his electron theory provides him with a proper deduction concerning the distribution of energy over regions of different wave length, which is being radiated by the electrons of a metal in their random thermal motions and collisions.

For the first time in history the spectral distribution of energy in temperature radiation is deduced directly from the mechanism of the process of radiation. The result only confirmed the well known formula of Jeans, which, however, fails in the range of low temperatures and short radiation waves. It was now clear that the problem of radiant energy could not be solved by making use of the theories, nowadays known as "classical" theories. One was

forced to accept Planck's wholly incomprehensible assumption that energy can be radiated only in definite quantities. The notion of the quantum of energy entered into the theory of radiation, and herewith a new chapter in science was initiated. The chapter previous to this, the chapter of the theory of electrons, had been written by Lorentz.

III. THE LORENTZ TRANSFORMATIONS

Astronomical aberration. The theory of electrons presents another angle which has cosmic significance and which lies in the phenomenon of astronomical aberration. Ever since the Copernican theory of our planetary system had been accepted, and the distances between the planets were known, astronomers desired to discover also the distances between the earth and the fixed stars, or at least some of them. One could calculate these, if, through careful observation, one were able to determine the difference in the position of a star, due to the fact that the object was viewed from different points, that is the parallax. In order to accomplish this, one must choose two different moments, namely those periods at which the earth is at opposite points of its orbit, at the extreme ends of the diameter which is perpendicular to the line of vision in the direction of the star. If a fixed star happens to stand in the axis perpendicular to the ecliptic, it would seem to describe a small circle in the course of one year. If the star stands elsewhere in the sky, an ellipse may be expected, and for the stars in the zodiac a small straight line. In the eighteenth century (1729) James Bradley discovered, due to his careful and patient observations, in fact such displacements of the fixed stars, but not quite in accordance with his expectations. In the case of the parallax one expects the view line

to be shifted towards that side where the centre of the orbit of the earth is. The displacement discovered by Bradley, however, always pointed in the direction of the velocity of the earth in its orbit. Bradley's discovery received the name of astronomical aberration. He explained this phenomenon as resulting from a cooperation of the velocity of light and the velocity of the earth. If one adheres to Newton's corpuscular theory, the explanation is simple enough. When seated in a railway compartment, we all have often witnessed that by reason of the velocity of the train, the raindrops, which normally descend perpendicularly, appear to fall in a slanting manner upon the windows of the train, and therefore appear to come from a direction which varies from the vertical. It seems to come from a point in front of the travelling observer.

Explanation with the aid of the wave theory. One may readily understand that Fresnel tried to explain astronomical aberration by means of the wave theory. But this is less simple than to do so by means of the emission theory. In order to explain why the degree of aberration is always the same, no matter whether one uses, for the purpose of observation, a mirror telescope, a refractor or a telescope filled with water, Fresnel was forced to accept the dragging coefficient for the ether by ponderable bodies. It fell to Lorentz to explain Fresnel's dragging coefficient by means of his theory of electrons, a coefficient subsequently affirmed by means of brilliant and convincing optical tests in running water by Fizeau, Michelson, and later by Zeeman.

Stokes had framed a theory in explanation of this aberration which rested on the idea that the earth would draw the ether with it in an absolute sense, so that no

"etherwind" could exist, either without or in our laboratories. Lorentz carefully pointed out that this assumption was inconsistent with another one that Stokes equally needed in connection with his attempted explanation, namely the idea that there are no vortices in the ether. After that, spanning Huygens and Fresnel in one grand stroke, he made clear that, if only one could be sure of the dragging coefficient of Fresnel, it would be possible to do more than only to explain the phenomenon of astronomical aberration. In all optical experiments which it is feasible to do on earth, with an accuracy of one in ten thousand, it would be impossible to detect any sign of the earth's motion through the ether. This limit of accuracy of one in ten thousand is mentioned here because it is approximately the relation of the velocity of the earth to the velocity of light, and it is this very relation which needs must determine the extent of a possible effect.

Explanation of Fresnel's dragging coefficient. At this point it becomes important to explain Fresnel's dragging coefficient theoretically. Lorentz uses a typical method of attack. In the same sense in which one may transpose an arithmetic problem in which 7 is the basic number, to another in which the decimal system is used, and after obtaining the result, retranslate it again to figures derived from the septenary system, thus Lorentz transposes the problem of light waves occurring in a moving piece of glass to those present in an immovable piece of glass, the nature of which is already known. The result obtained is then figured back to the desired result in the original problem.

This transposition occurs in two steps. The first one concerns space and time, the co-ordinates as they are

termed. The space and time elements of the event under consideration, in which we find a piece of glass moving uniformly and parallel to itself, are transposed to another space and another time in which a similar event will occur, except that now the piece of glass will be at rest. Time and space, to speak in a metaphor, are pulled askew a little bit. As far as space is concerned, the transposition means that a stationary particle in the new space will correspond to a particle which in the original event is moving with the same velocity as the glass. This new space is as it were fixed to the glass. As to time, the transposition means that at all points within the new space we count with a slightly readjusted local time, comparable to what is being done everywhere on the face of the earth where local mean solar time is used in accordance with the local meridian instead of absolute stellar time, figured by the meridian of Greenwich.

In the second place the field also is transposed. If, as assumed in the original case, we have a magnetic field caused by a fixed magnet then a charge moving with the glass will be affected by the force which we have named the Lorentz force. The transposed electric field, according to Lorentz, is to be understood in terms of the total force acting on a charge which moves with the glass and which itself remains immobile within the transposed space. In an analogous fashion the magnetic field force is transposed. If, in the original case, we have an electric field caused by charges on two fixed parallel plates, then, in the transposed case, the plates will move, let us say in a direction parallel to their plane. This means of course that we are faced with convection currents, and therefore with a magnetic field. The latter Lorentz adds to the magnetic field present before the transposition, in order

to arrive at the value of the transformed magnetic field force. In such a way the field is transposed.

The importance of these transpositions is found in the fact that the phenomena in the transposed field occur according to the same formulae which figured in the non-transposed field; at all points the events in both cases correspond. The second event deals with the propagation of light in a motionless piece of glass. We are already acquainted with this. By means of re-transposition we then come to know the nature of the propagation of light in a moving piece of glass.

This method yields to Lorentz the dragging coefficient of Fresnel. However, in this theory the notion that the ether really might be dragged along is completely eliminated. Lorentz' ether stands unmoved and immobile, even more so than Fresnel's ether.

Highest degree of refinement. The theory described conclusively indicated that the relative motions of the ether and the earth could not affect optical phenomena, even to a hundredth of one percent, but nevertheless the problem was not left at that. The theory did not exclude the possibility that still another effect might be present. Indeed it even postulated that in the case of experiments conducted with a degree of accuracy up to a millionth of one percent, an influence of etherwind moving with a speed of thirty kilometers per second should be felt. Michelson in 1881 had conducted such a highly refined experiment, suggested by Maxwell in order to determine the relative motion of the earth and the ether. The result was: the relative motion is equal to zero. Due to Lorentz' observation that Michelson had made a mistake in the estimate of the result to be expected, Michelson, together with

Morley, repeated the experiment in 1887, and this time with a greater degree of accuracy. The presence of ether-wind could not be shown.

The result seemed ominous for Lorentz' theory, and yet, in spite of the experiment, he could not accept the fact that the earth dragged the ether along. There seemed to be but one way out. He concluded that all solid bodies, in this case the parts of Michelson's instrument, diminish their dimensions a tiny bit in the direction of the ether-storm which affects them. It took courage to accept this postulate, which seemed a foolish whim, and which in any case seemed to be revolutionary to an excessive extent. Nevertheless, Lorentz could point to the fact that electromagnetic forces between charges do change somewhat, due to their motion. It followed that if the nature of the forces which keep the molecules in solid bodies in their fixed position, and which determine the dimensions, would be of the same kind, then they ought certainly bring about a contraction of the size mentioned. — A similar hypothesis had been advanced by an Irishman, Fitz Gerald. — It lasted fifteen years before Michelson's experiment was followed by related supplementary experiments by Trouton, Noble and Rayleigh. Lorentz' conclusion that no etherwind effect existed found its final confirmation. In 1904 Lorentz was able to combine the results of these experiments and, by means of a further refinement of the transposition method already mentioned, explain their significance.

Through this "pulling space and time askew", that is, by shortening distances in the direction of the movement by a two millionth part of one percent, and by causing time to move slightly slower in the same ratio, and, finally, through a corresponding correction to the trans-

posed electromagnetic field dimensions, he was able to raise the mere approximate similarity of the basic equations in the transposed case to the level of exact similarity. The equations showed complete invariance, as mathematicians say. Thereby this theory once and for all established the fact that no experiment would ever reveal signs of a joint collective translation of all parts involved in the experiment.

This transposition received the name of the Lorentz transformation of co-ordinates and time. After Einstein the same theory came to be known as the theory of relativity. Einstein developed it into a more general theory, which included gravitation and which became victorious in astronomy.

IV. THE TURN OF THE CENTURY

Completion of the old and base for the new theories. We have had a bird's eye view of Lorentz' scientific accomplishments. Many details have been omitted and the summary is hardly complete. When we review Lorentz' opera in toto it becomes clear that he took over the nineteenth century, scientifically speaking, into the twentieth. He completed whatever his great predecessors had left unfinished. All that lay involved in the great concepts of Huygens, Fresnel and Maxwell, he brought to a clear conclusion in his theory of electrons. No one could have advanced the classical theory farther than he did. He made it into a firm foundation for all who would have to build after him. He drew from it the utmost consequences. He carefully proved that this theory yielded no explanation of the new radiation phenomena. He was now ready to accept the new axioms of the quantum theory, no matter how daring they might seem to be, provided

always that they were distinctly formulated and provided the consequences were clearly drawn so that they would show no inner discrepancies. In this respect he manifested throughout his life an unusual degree of receptivity, which kept him young and which made him have confidence in the younger generations who came after him. He was utterly unselfish regarding these matters, and through the strength of his character he always prevailed over all that might have turned to be a tragic reverse of his work.

The invariance of the laws of nature had already been postulated by him in 1892. Through the long years of his life he pursued step by step that idea and by devoted and patient labour he arrived at the invariance of the laws of nature under his transformations, we say: under the Lorentz transformations. Yet he did not quite reach his goal as far as the electric current and charge were concerned. He often admitted that this was reserved for Einstein. The fruits for which he laboured were harvested by another when the time proved ripe. He did not grudge Einstein, he admired him and encouraged him when this scholar broadened the scope of his theory of relativity and proceeded from the consideration of uniform translations to a new theory of gravitation. He accepted those theories wholeheartedly and made his own light to shine upon them.

The Zeeman effect, which promised to yield a complete confirmation of the classical theory through what is termed the "normal" magnetic splitting of the spectral lines, placed the originator of this theory before an unsolvable problem when the sodium lines, which figured in its discovery, would not split into three, which would have constituted a "normal" triplet, but into four and

even six components. Again and again Lorentz sought a way out but always without success. Only towards the end of his life Goudsmit and Uhlenbeck discovered that, if in addition to their charge the electrons were allowed to possess a mechanical spin and a magnetic moment, it became possible, with the proper use of the axioms of quantum theory, to understand the rules governing this anomalous splitting.

Classical and modern physics. Lorentz sympathised wholeheartedly with modern physics. After the first world war he was always engaged in defining more clearly the nature of the problems and the methods of their treatment. Basically, however, his roots remained in the soil of the 19th century.

The younger group of physicists had no difficulty in reaching the conclusion that, if the experiments showed that no ether was present, it would be just as well to say that the ether did not exist except as a mental concept to indicate the magnitude and the duration of the phenomena. And they added that, if, as the result of the absolute invariance of the laws of nature, it did not matter in the least which scheme of space and time one chooses for the description of the texture of events, there is no merit in continuing to use the phrase "absolute simultaneity". Lorentz, though acknowledging that it never would be possible to detect motion in the ether, did not renounce the idea that there might be some objective sense in speaking of velocity with respect to the ether, and that equally it might make sense to speak of absolute simultaneity.

After Lorentz had completed the separation between the convection current of charged matter and the dielec-

tric displacement current in the ether, the modernists experienced no difficulty in following Minkowski in uniting the electric and the magnetic field forces into one quantity. They could therefore assert that in the same sense that there is no reason to assume that in a magnetic field a displacement of magnetic fluidum occurs, it is equally unreasonable to believe that the displacement of an electric fluid in an electric field could be other than a mental fiction. Lorentz did not agree. He would not allow anyone to question the usefulness of the visual interpretation of Maxwell's theory, the incompressibility of the electric current. The dielectric displacement currents in the ether remained to him the continuation of the conduction current, and in their effect equivalent to them.

Similar matters of interpretation often appeared to Lorentz to be mere questions of the use of words and of taste. He used to attribute little value to them. The proof of all interpretations, thus he reasoned, is found in the silent, strict logic of the calculating play with mathematical equations, which he, aided by his profound knowledge and wisdom, handled in a masterly fashion, and which infallibly revealed to him the discrepancies involved in error and the trustworthiness of truth.

REMINISCENCES (continued)

BY

G. L. DE HAAS-LORENTZ

ACTIVITIES APART FROM HIS SCIENTIFIC WORK

Already as a young Professor Lorentz was regularly consulted not only about scientific matters, but also regarding affairs concerning the University. W. Martin, German Professor of Geology at Leyden till 1922, once told me a nice story about this. Shortly after Lorentz' appointment as Professor, Martin had to deal with a crystallographic problem. He decided to consult Lorentz and explained the problem to him. Within a few days he (Martin, that is) received a perfectly clear and short paper from his young colleague, and, as he added, "to my amazement in perfect German"¹⁾.

From the very beginning Lorentz' lectures stood out by reason of this same clarity, and they remained so, even increasingly, until he delivered his last lecture shortly before his death. Often topics of actual interest were discussed in his lectures, which was rather unusual in those days; he would also deal with the work upon which he was engaged at the time, although his students might not

¹⁾ This manuscript is still in my possession.

be aware of this fact. I remember how surprised and interested Max Planck was when during a visit to Leyden, he discovered that my father was lecturing on Planck's concentration currents.

The classical theories were presented in a wholly original way, resulting from Lorentz' deep insight into them. It is not surprising that my father soon felt the need of a new textbook for his students. Thus the well-known book: "H. A. Lorentz, Beginselen der natuurkunde", in two volumes (Brill, Leyden) appeared in 1893.

This is the proper place to quote from an article by W. J. de Haas, which appeared in a little volume entitled "Professor Lorentz"¹⁾: "Many years before I went to Leyden and was still living outside of the University circle, I came to know Lorentz' well-known textbook. While reading it I was impressed and interested by the unusual style of argumentation, entirely different from other textbooks, concise and exact in every way. The book presented a masterly constructed synthesis of physics, in its actual development.

I was very anxious to see the author of this book and to hear him. He had the reputation of being the world's leading theoretical physicist of the period. My mind still retains the picture, as clearly as though it were fixed on a photographic plate: how he entered the classroom, of slight build, his hair dark, almost black, of dominant appearance. At the beginning of the lecture he would speak rather hesitatingly, but after a while he would develop his argument quietly and in simple sentences, which left the impression of great precision and refinement".

¹⁾ It was part of a Dutch series which bore the name "Contemporary Subjects", and which was published at the instance of the I.V.I.O. in January 1953.

Going back to the textbook: in order to make it useful to students who had not studied differential and integral calculus, the author in his deduction of formulae made use of no more mathematics than taught in the secondary schools, not even in the deduction of the velocity of light. This textbook went through nine editions. Unfortunately, after the last edition in 1929, it proved that the subject matter had expanded so much that no room was left for the careful development of the electromagnetic theory, which Lorentz had given in his book.

Long before this book had appeared in print, Brill had published, in 1882, H. A. Lorentz' textbook on differential and integral calculus, meant for physicists and chemists to teach them mathematics with a view to application to their own subject. In later years this small volume was unfortunately not used to the extent warranted by its great merit. This has always astonished me greatly, as well as many others. Professor H. D. Kloosterman¹⁾, for instance, when in 1936 he became acquainted with this book for the first time, was astonished to find it a manual, giving to the science students in a masterly fashion all the mathematics needed for their later theoretical computations, at least up to the time of the quantum and wave theories. According to Kloosterman this book derives its value from the circumstance that it shows clearly how mathematical concepts originate through a process of abstraction resting on conclusions drawn from the careful observation of the facts of experience.

Professor Fokker somewhere divides the period of Lorentz' professorship into two parts. How right he is! It is significant to observe how my father, after twenty-five years of professorial duties, during which he gave all his

¹⁾ Professor of Mathematics at Leyden from 1947.

time to study and to official obligations in the wider sense of that term, gradually came to belong to his entire country and to the international scientific world at large.

In 1881, when he was 27 years old, Lorentz became a member of the Royal Academy of Sciences at Amsterdam. Professor A. J. Kluyver, President of the Department of Physics, said on January 31, 1953, that, "through this membership the Academy had gained a scholar, who not only was able to look back upon a most commendable past, but who also was in the very midst of a dynamic state of development".

When the textbooks had been completed, and the conditions regarding practica and the preparation of experiments in connection with his lectures had somewhat improved, gradually more time became available for engagements outside of the University. Thus my father delivered in 1882 his first popular lecture before the Society "Diligentia", which was followed by many more during the course of the subsequent years. Soon Lorentz came to be known for his interesting and clear way of lecturing. It will interest my readers to know that he prepared his lectures carefully, occasionally without committing them to writing, and he always delivered them from memory. Of the many different addresses which my father delivered, I should like to mention a lecture course, part of a series of scientific and cultural addresses, which together constituted a University extension course, sponsored by the Society "Nut voor 't Algemeen" (1900-1901). The little volume containing these lectures was translated into several languages. My father himself was an admirer of good popular lectures, which in the nature of the case may attain to a higher degree of elegance and style than an ordinary scientific composition. How often have I

heard him recommend to me and others the popular lectures by Helmholtz and Tyndall as literature fit to be read when one was recuperating from an illness. How enthusiastic he was in later years about the "elegantly written" interesting booklet by Jean Perrin "La réalité moléculaire".

Lorentz loved to give popular and semi-popular lectures. It was a great satisfaction to him to make his untrained audience follow his line of thought and to make them realise the beauty of the phenomena under consideration. He told me later that he enjoyed most of all lecturing in the "Leidsche Volkshuis"¹⁾. In this connection I want to mention a delightful encounter. In the "Volkshuis" my father attended a lecture by Frederik van Eeden²⁾, I think it was about the year 1902. Van Eeden spoke about philosophy and pointed to the fact that it was absolutely necessary to know the positive meaning of each word employed in connection with this discipline. He deplored the fact that this was not sufficiently so in the writings of most philosophers. To his knowledge the only author who came up to these requirements was Professor Lorentz. Van Eeden was a physician and therefore acquainted with my father's text books, as well as with other articles of his. He had never met my father and did not know that he was in the audience, sitting at the back of the room. Naturally my father was very surprised about this unexpected opinion regarding his work. That evening the two interesting men met, and since then corresponded with one another for many years.

The first twenty years of Lorentz' professorship have gone by. His scientific publications deal with many dif-

¹⁾ An institution of the same kind as Cooper's Institute in New York.

²⁾ Famous Dutch author.

ferent subjects; among these writings are those which are to form the foundation of the theory of relativity, and those which present the explanation of the electromagnetic phenomena through the introduction of the concept of the electrically charged particle, to which later the name of electron will be given. Through this Lorentz became the discoverer of the electron and the creator of the theory of electrons.

FIRST SCIENTIFIC CONTACTS ABROAD

It was not until 1900 that my father began to make contacts with other physicists abroad. Our descendants, even more than we ourselves and our contemporaries, will wonder how this was possible. Why is it that my father during those twenty years never tried to establish contact with other scientists of interests similar to his own, and how is it possible that these never tried to become acquainted with him? Even with Maxwell, who died in 1879, my father could have made contact had he so desired. It would have seemed the most natural thing in the world to send Maxwell his thesis and also to forward a few copies to foreign scientific periodicals. It is a pity that he never did this. A few years earlier, in 1873, Maxwell did read the thesis of van der Waals. This is evident from an article in "Nature"¹⁾ which he finishes with the following words: "undoubtedly more than one person, having read this thesis, has had his attention directed to the study of the Dutch language". This would point even to the fact that he had read the thesis in the original language. At that time there was in England much more interesting intercourse between physicists than in the Netherlands.

¹⁾ Nature 10 (1874) 477.

To my father the contact with physicists such as Kelvin, Fitz Gerald and with the young J. J. Thomson would have been of great value.

Helmholtz was the leading physicist in Germany; he was Professor at Berlin, the director of a large laboratory. Helmholtz, who was ten years older than Maxwell, had studied the writings of the latter with great interest and had published several articles dealing with the same subjects. Indeed, as was mentioned in the introduction, it was due to a remark made by Helmholtz that Lorentz had undertaken the research published in his thesis. The principal lecture given by Helmholtz in connection with the solemn commemoration of Faraday by the "Chemical Society" in London in 1881 proves that also in England this German physicist had established a great reputation.

While many experiments in connection with Maxwell's theory were made in England, as well as in Germany, nothing of the kind was done in the Netherlands. Here my father was the only person occupying himself with these subjects, and that without any other contact with the outside world than by means of scientific publications. Probably on account of his modesty, but even more so by reason of a certain measure of indifference and of a lack of appreciation of the pleasure and value involved in the intercourse with other workers in the same domain, young Lorentz left his Dutch publications untranslated and therefore confined to the Netherlands.

The picture of the life of a scientist at the end of the 19th century gains in clarity when one remembers the peace and quiet of the daily life at that period, particularly in a small town such as Leyden. One must try to picture streets without automobiles, traffic without aeroplanes, streets so quiet that we children could go to school safely,

playing with our tops. There were few visitors from abroad and few trips to foreign countries. What a wonderful opportunity for uninterrupted study for scientists without the interference of numerous trips to congresses in all parts of the world. By way of illustration, let me mention an instance which happened about 1892. We were sitting round the luncheon table and my mother happened to mention how someone told her of seeing a stranger in the Breestraat, the principal street of Leyden, but which at the time was so quiet a thoroughfare that one could have emptied a gun in it without hurting anyone. The stranger, it was said, looked like a foreign professor. My father's wholehearted reaction was "I hope he will not turn out to be a physicist".

Those years of uninterrupted, fruitful study, without any personal contact with the world outside, were undoubtedly happy ones for my father. They lasted until about 1895. He did not miss the association with other gifted colleagues, interested in the same phase of physics. The stimulation and pleasure offered by the scientific discussions with these he came to know only in 1897, when, due to outside pressure, he attended for the first time an international congress, namely the "Versammlung deutscher Naturforscher und Ärzte" in Düsseldorf. Seldom have I seen my father in such good spirits as after his return from this congress. Here, and at other Naturforscher Versammlungen, he made the acquaintance of many German physicists such as Voigt, Ebert, Wien, Röntgen, Cohn and others. A close friendship with Voigt was the result. Helmholtz died in 1894. Also he, whose work my father appreciated more than anything else, Heinrich Hertz, by four years the junior of Lorentz, had died shortly before Helmholtz, in 1894. That my father never

became acquainted with Hertz would for ever remain a source of great regret to him.

Within a few years those conferences were followed by others, even more important ones, which Lorentz attended and where he made contact with the physicists in France and England. In 1900 he delivered an address at the "Congrès international de Physique" in Paris "Sur la théorie des phénomènes magnéto-optiques récemment découverts"; this in connection with the Zeeman effect. In 1902 my father, accompanied by my mother, went to Stockholm, in order to receive together with Zeeman the Nobel prize. It was the second time that this prize was presented. According to the statutes of the Nobel Foundation the prize was intended for outstanding merits in the field of experimental physics. By reason of the fact that the Zeeman effect unquestionably owed its significance to the theoretical explanation which Lorentz gave of it, and by which he predicted the particular characteristics which this phenomenon would show, the Swedish Academy saw fit to change its rule, by presenting the Nobel prize to Lorentz and Zeeman together. In later years this statute was apparently changed, or at least was given a different interpretation; many theoretical physicists have received the Nobel prize since.

In this same year my father was asked to write for the "Encyclopaedie der mathematischen Wissenschaften" (Teubner) the articles on Maxwell's theory, the theory of electrons and the magneto-optical phenomena. In 1904 a lecture on "Ergebnisse und Probleme der Elektronentheorie" was given before the "Electro-technischer Verein" in Berlin. This lecture gained such a wide fame, that among physicists it was simply called "Ergebnisse".

In 1905 my father delivered a lecture before the "Société

française de physique" in Paris on "La thermodynamique et les théories cinétiques". This lecture was published in French and was translated also into German and Polish. Since that time the number of friends that my father made among the French physicists increased gradually. I may mention in this connection: Poincaré, Marcel and later Léon Brillouin, Pierre and Marie Curie, Paul Langevin, Jean Perrin. The best known of several lectures given by my father in Paris, was the series held at the Collège de France in November 1912, published in bookform under the title "Les Théories statistiques en thermodynamique"; this book appeared only in 1916, due to the outbreak of the first world war in 1914.

FIRST TRIP TO THE UNITED STATES

In the early years of the twentieth century, few journeys for scientific purposes were ever made to America. My father's first trip to America was such an important event that several of his students came to the station to see him off. This was in the spring of the year 1906. For six weeks my father lectured at Columbia University, New York City. These lectures were published in book form with supplementary notes by Teubner and bore the title "Theory of electrons". Since my mother's ill health did not permit her to make the trip, I had the privilege of accompanying my father. The recollections of this trip are among the most precious in my experience. I should like to mention a few at this point.

First of all there was our West-bound trip across the ocean with the Holland-America Line. My father was looking forward to this chance of becoming acquainted with the United States, showing a degree of enthusiasm

which one would expect to see in a young man. Many of our fellow travellers were young people who were going to the United States to try their luck, some in one way, others in another. Some of them went with the assurance of finding kind help and support in the new country, others with the knowledge that they would have to fight their own way through. All of them were looking forward, with hope and expectation, to life in the new world.

We were all much impressed when we entered the mouth of the Hudson river and saw the Statue of Liberty which welcomed us to the free world; we were greatly touched by the beauty of this symbol. In New York Professor Ernest Fox Nichols (who in 1903 together with Hull had measured the pressure due to radiation) had rented for us a small apartment consisting of three rooms in the same house in which he, his wife and a young daughter were living. The house was situated on 118th Street West, and bore, like all apartment houses, a beautiful name, in this case: the Naraganset. On the one side it looked out over Morningside Park, while the opposite side gave on 118th Street, which would take us in a few minutes to Broadway, close to the rear of Columbia University, the main entrance of which was found on Riverside Drive along the Hudson. It was an "apartment without cooking, only water". This stood us in good stead. At the very first meeting with the members of Columbia University my father had been warned against the New York drinking water. In 1906 neither New York nor some of the other large cities in the United States had a reliable water system. During our whole trip therefore we were careful not to drink one drop of unboiled water. Thanks to this precaution we had the good luck not to suffer one day of illness, something, our hosts told

us, that had never happened to other European guests. One would see many visitors in restaurants dissolving disinfectant tablets in their drinking water, the same kind of tablets which in the second world war were included in the military ration packets.

How greatly my father enjoyed his trip! This made everything for me doubly pleasant. We both had the feeling that we were on holiday, although my father had a great deal of work to do. This proved how easy it was for him to deal with matters which demanded strenuous effort. This was a blessing both for him and for the many who might be able to profit by his great gifts. Many years later, when my father made a number of trips to the United States at a time when he was much older, or even had reached an advanced age (his last visit was in the autumn of 1926), we were often worried about the exertions to which he was exposed. We took renewed comfort, however, from reminding one another that it was my father's brains that kept him going, and that through the strength of his mind he would be able to continue with his strenuous work.

During his first journey my father was in possession of his full physical strength. We certainly enjoyed everything and had many a good laugh. Our lighter moods were most evident when we were on trips away from New York and during such hours as my father could devote to me. It was a good thing that occasionally I succeeded in taking him away from his work.

His time was fully occupied, due to the fact that physicists from all over the United States came to him with scientific questions and problems. Among them were some who had to travel eight hours back and forth once a week in order to attend regularly Lorentz' lectures which were

held on two or three successive days. In case my father could not find the time to receive those who laid a regular siege to him, they would find some way of accompanying him while he was walking from one building to another; and would then pose their questions to him. I have often been afraid by the danger to which those "shop talking" physicists exposed themselves in the midst of the crowded New York streets.

The New York traffic stands out in my recollection as one of the most interesting things I encountered: no automobiles at that time, only electric trams, one after the other, and then a never ending stream of horse drawn vehicles which filled the entire width of the streets. If the traffic was stopped, in order to give the pedestrians a chance to cross, these were forced to make their way across, literally underneath the horses' heads. Ladies, however, would always be sure of finding someone courteous enough to help them across the streets. There were very few automobiles at that time, at least we did not see any. Two of them belonged to Mr. Cooper, the head of Cooper's Institute in New York, which corresponds to what in Holland we would call "Volkshuis".

Through the intermediary of a good friend, Professor Pupin of Columbia University, Mr. Cooper, one morning, placed one of his automobiles at our disposal, and we were driven through the City of New York. When we were back in Holland, someone asked my father whether he had been afraid. His answer was "not at all, I had the impression that the driver had better control of his automobile than the coachmen of their horses".

When it came to a matter of horses, we had somewhat unpleasant experiences in Washington where we were the guests of Simon Newcomb. This astronomer had

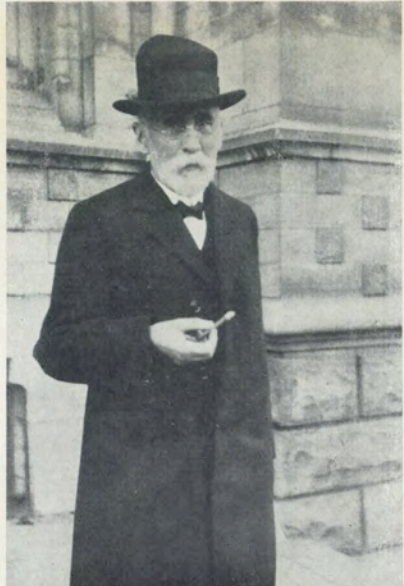
made a name for himself both as a scientist and, also in the Netherlands, with his book "Popular Astronomy". Professor Newcomb owned a horse and buggy, but was peculiar in this sense that he insisted on using only horses which were not yet broken in. His coach, driven by a negro coachman, would sway through the streets. At one time one would almost bump into an electric tram, and then again, when driving around a corner, one would find oneself halfway on the pavement.

During this first visit my father became acquainted with most of the prominent physicists in the United States. They all admired him, and showed their admiration on every occasion. They did all they could to make him, their beloved guest, and with him his daughter, comfortable. I wish to mention in particular the names of two men whose recollection dwells in my mind most clearly, namely Pupin and Webster. Greatly pleased was my father each time he saw the faces of those two men at a reception or some other occasion. They were always ready to help him and please him. How often did they protect him against the assaults of kindly, but rather aggressive American women, or saw to it that he would have a quiet half hour for a talk with a few interesting people. Webster was the author of a well known textbook on mechanics "The Dynamics of Particles and of rigid, elastic and fluid Bodies" (Teubner). Pupin was the inventor of long-distance telegraphy with the aid of induction coils. He had had a most interesting career and loved to tell us about his experiences. A son of simple peasants in the Banaat, the Northern part of Serbia, he came to the United States as an immigrant at the age of fourteen. When we were back in Holland, he sent my father his autobiography "From Immigrant to Inventor", a book

which I recommend to everybody. The author gave it the interesting dedication "To the idealism of American science". Through his inventions Pupin had become very rich. Together with many prominent people he formed an organisation for the purpose of creating contacts between scientists and prominent people in society who might be expected to take an interest in science to such an extent that they would give it financial aid, as was the case with the "Hollandsche Maatschappij van Wetenschappen" at Haarlem. This organisation carried the name of "The Electrons"; naturally they gave a dinner in honour of the discoverer of the electron.

My father had been very happy during his six weeks' stay in New York and other cities in the United States, and he said farewell to the New World with great regret. He little expected that he would return to America three times, accompanied by his wife, at the invitation of the University of Pasadena. These trips took place in the years 1922, 1924, 1926. During these visits he was showered again with tokens of respect and friendship. In evidence of the delight felt by the staff of the Norman Bridge Laboratory at Pasadena to having him with them, they gave him a small golden key of the laboratory. This key is now in the National Museum for the History of Science at Leyden.

In Pasadena my father came into close contact with Professor Hale and his assistants at the Mount Wilson Observatory. They often came to him for help and advice. They even tried to make him a consultant member of the Mount Wilson laboratory as successor to Professor Kapteyn of Groningen after the death of the latter in 1922. However, my father had no time to assume this new duty.

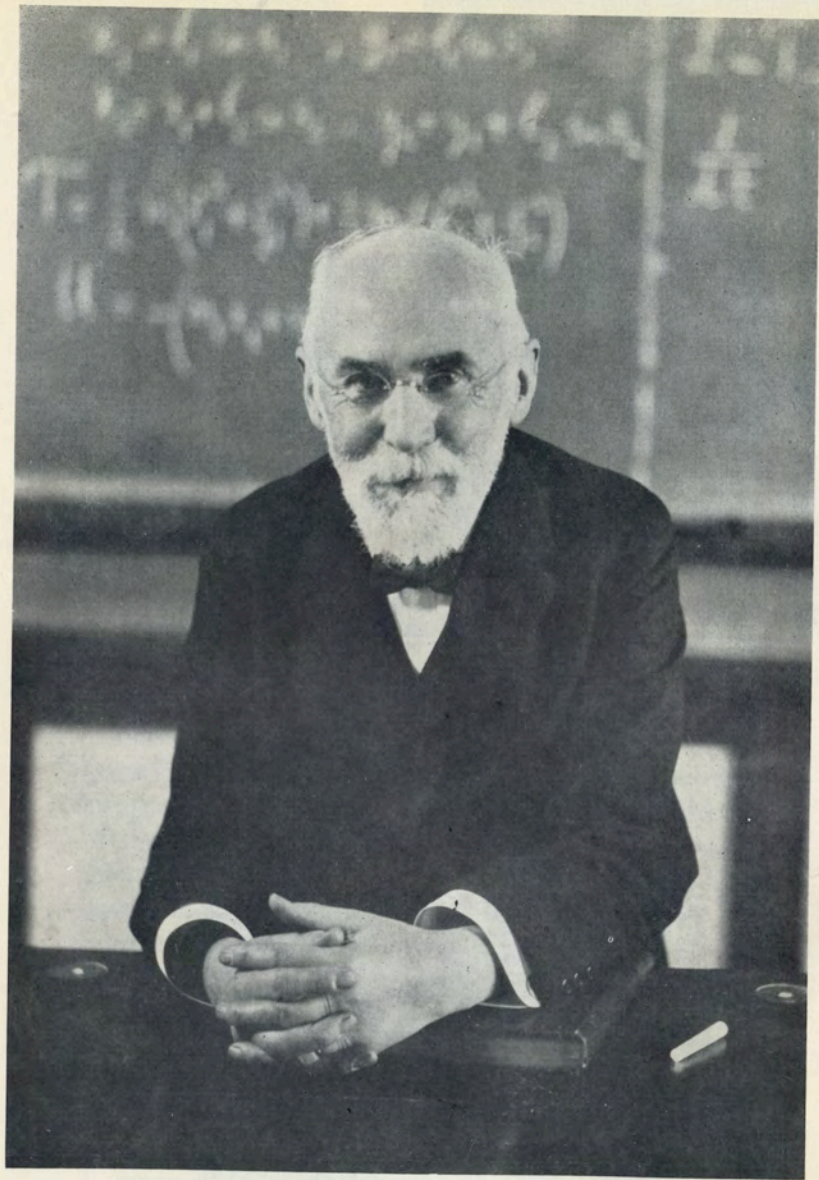


On Mount Wilson, Febr. 1924
On the left Prof. and Mrs Lorentz

Brussel 1927



Pasadena, with Prof. Millikan 1927



Ithaca N.Y. 1926

He nevertheless kept in close scientific contact with Hale until the end of his life.

On his trip back and forth to California he lectured in several cities. In New York the old ties with Columbia University were strengthened. In combination with these travels in the interest of science, my parents had a few outings devoted to mere pleasure.

LAST YEARS IN LEYDEN, MOVE TO HAARLEM

On Lorentz' return to his country, after his first visit to the United States, at the opening of the academic year, an improvement in the conditions under which he had to work awaited him. The year before, the University of Munich had offered him a professorship at far better conditions than the ones under which he worked at Leyden. This appointment had been under consideration before, but my father, loving his country and used to his quiet surroundings, had not accepted this offer. In 1905 the busy life of lecturing, examinations, together with the great demand made upon him by his colleagues of different nationalities, became too heavy a burden for my father. When the invitation to come to Munich was repeated emphatically, he seriously considered this call. Only after his position in Leyden had been improved considerably he decided to remain loyal to his old university. Offers from America could not change his decision either. The government wanting to ease Lorentz' burden of teaching appointed as a third Professor of Physics, who would take over the teaching of the first year students, J. P. Kuenen, a pupil of Kamerlingh Onnes, then Professor at Dundee who arrived in Leyden in the summer of 1906. It was a wise and good move on the part of the government of

the Netherlands, thus to retain Lorentz for his country.

At the same time my father was also given an assistant, whereas a new addition to the laboratory was constructed which contained a lecture-room, a room for Lorentz, one for his assistant and two small laboratories for experimentation, which were intended for Lorentz' personal use. This accommodation, which he had greatly lacked and had asked for, was now given him. He liked to do experiments himself, just for the sake of pleasure. Probably through a mistake, those two rooms were "temporarily" added to the large laboratory. I remember very well how disappointed my father was at the result of this "administrative" measure. However, the matter was not discussed. My father preferred, rightly or wrongly, to keep his peace of mind rather than to create a disturbance unless it were strictly necessary.

Still, I believe that this little incident made him more anxious than otherwise would have been the case to accept in 1911 an offer made by the directors of the "Teyler's Stichting", together with the Board of the "Hollandsche Maatschappij van Wetenschappen", both at Haarlem. This offer involved a double function, namely that of "curator" of "Teyler's fysisch Kabinet" and the secretaryship of the "Hollandsche Maatschappij van Wetenschappen". My father accepted this call, and thus profited but a few years by the improved conditions at Leyden. In 1912 he resigned his professorship and moved with his wife and his son to Haarlem¹). At Leyden he

¹) Both his daughters were married, the elder, author of these reminiscences, to Dr. W. J. de Haas, later successor to Kamerlingh Onnes as Professor at Leyden and Director of the "Cryogeen Laboratorium", the younger daughter to Mr. H. C. Leemhorst, later Mayor of Hoorn.

The son would marry Miss M. C. van Vollenhoven, a niece of the well known Professor Mr. C. van Vollenhoven at Leyden.

continued as "Professor Extraordinary" to deliver his famous Monday morning lectures, which he would continue for the rest of his life.

On page 96 I already mentioned the "Hollandsche Maatschappij van Wetenschappen" together with its purpose. I also related how my father as a young professor made the acquaintance of Bosscha, then President of the "Polytechnical School", and I mentioned how the latter became from the first much attracted by young Lorentz. In the course of the years this appreciation turned into admiration. Bosscha during many years was secretary of the "Hollandsche Maatschappij van Wetenschappen". This position involved more than the simple duties connected with a secretaryship. Bosscha lived on the other side of the river Spaarne in a large house owned by the Society, which he needed by reason of the many representative duties connected with his position. Bosscha, a long time ago, had suggested his own resignation and the appointment of Lorentz in his stead in the hope of providing for the younger physicist better conditions for his studies¹). My father, however, had not approved of this plan, mostly because the representative part of this work did not attract him. Thus Bosscha kept his function as secretary until he was well along in years; then Lotsy became his successor. When a few years later the latter died, the "Hollandsche Maatschappij" again offered the position of secretary to my father. This function would be divested from everything that made it objectionable to Lorentz, and the Society undertook to make his duties as pleasant as possible to him, giving him plenty of opportunity for self-study. Since no representative duties would devolve

¹) Coll. Papers IX 403.

upon my father, he could live in a smaller house (76 Zijlweg) instead of in the mansion belonging to the Society on the Spaarne. He moved from the house on the Zijlweg to one in the Julianastraat in 1920. Part of this street was named Lorentzplein after his death.

Opposite the house belonging to the "Hollandsche Maatschappij van Wetenschappen", on the other side of the Spaarne, the building of the "Teyler's Stichting" is situated. Both foundations are Haarlem institutions, and date from the 18th century. The "Teyler's Stichting" possesses a numismatic cabinet, a museum of paintings and drawings, a cabinet for physics together with a laboratory and a historical collection of instruments. A curator was in charge of each of these institutions.

When the directors of Teyler's Stichting, together with those of the Hollandsche Maatschappij, planned to create a position for Lorentz which would be welcome to him and worthy of him, they decided to do this by means of a reorganisation of their physical laboratory. Planning this they directed their attention to England, and especially to the Royal Society in London, which for generations had been under the leadership of an eminent physicist, who also was in charge of the laboratory. Faraday worked here from 1812 till 1858. This was the reason that Teyler's direction decided to appoint a curator over the conservator of the physical laboratory, and enlarge the budget for the laboratory. In addition, the direction expressed the wish that the future curator would be found willing to be responsible for a course of semi-popular lectures in physics, to be given either by himself or by others. A series of lectures given for many years by Lorentz to teachers in physics, and after his death continued by Professor Fokker,

was the result. And Lorentz, at last, had his own little laboratory for which he had always longed.

One cannot be grateful enough both to the *Hollandsche Maatschappij* for its initiative in this matter, and to the directors of Teyler's Stichting for the sacrifices they were willing to make in order to give Lorentz a chance to devote himself freely to his own scientific work and to the duties connected with it. How many have profited, thanks to this fact, by the great talents possessed by this remarkable man.

While living in Haarlem Lorentz continued his famous Monday morning lectures in Leyden, first as Professor Extraordinary, later (1923) enabled to do this by a honorarium from the Leyden University Foundation. Einstein mentions these lectures on page 5, B. van der Pol does the same in the *Telecommunication Journal*¹⁾ with the following quotation: "Lorentz lived in an age which saw the beginnings of the quantum theory enunciated by Max Planck and the new theory of the atom elaborated by Niels Bohr. Although he worked within the framework of classical physics and both these theories were in violent contrast to classical views, Lorentz was one of the first to grasp their far-reaching importance and to realise the profound bearing they were destined to have on the future of theoretical physics.

It was his regular custom to communicate and expound these new ideas to his pupils in his famous lectures at 11 o'clock on Monday mornings at Leyden University. These lectures were of an exceptionally brilliant nature and their clarity proved his complete mastery of his subject. Among the audience in his small lecture-room

¹⁾ *Telecommunication Journal*, October 1953.

other great physicists of his time, such as Ehrenfest, Einstein and many more were often present. After expounding in these lectures the views of the originators of some new theories, he would often go on to point out the subtleties of the ideas or any slight inadequacy in the arguments used. And then, to use his own words, he would "turn the subject round and round and over and over". Thus he was often able to shed on it some new light of his own. In the next lecture he would usually go on with the subject and hardly anybody among the audience became aware of the fact that all that followed was his own creative work, often prepared only a few days before. Typical of Lorentz' genius was the great ease with which he could master physical subjects, even those, or particularly those which, in his time, belonged to the most difficult part of theoretical physics. This unique gift is clearly shown in the way in which he used to read scientific articles which his students occasionally submitted to him for criticism before publication. The quickest way for him to respond to such a request was as follows: first he read the beginning of the paper, where the theoretical problem was expounded; next he took a piece of paper and solved the problem himself; then he looked at the end of the article and if the solution was the same as his own he was fairly sure that the reasoning was sound.

His very great gift of elucidating complicated physical problems is also exemplified by the way in which he often responded to scientific questions put him by his colleagues or pupils. Instead of answering them directly, it was his habit to repeat the question in such a sharp and concise form that the answer at once became evident".

Who was to become Lorentz' successor? This was a difficult problem and Lorentz was aware of it. It was only after considering all the available candidates that my father advised the faculty to place on the list for possible appointment as Professor of Theoretical Physics Paul Ehrenfest, an Austrian by birth, a pupil of Boltzmann's and at the time living in St. Petersburg. His scientific work, particularly the article by Ehrenfest and his wife Tatiana Afanassjewa¹⁾ concerning the greater probability of the H-Function to decrease than to increase, followed by their joint encyclopaedia article²⁾ about the mechanics of systems with many degrees of freedom, was of great importance in his decision. But equally weighty, no doubt, was the well known brilliant manner in which Ehrenfest at the Polytechnicum at St. Petersburg presented to teachers and the more advanced students, *capita selecta* from modern physics.

Ehrenfest, together with his family, came to Leyden in the autumn of 1912. On the way he stopped for a few days with his friend Albert Einstein, who had recently been appointed research-professor at the Kaiser Wilhelm Foundation at Berlin-Dahlem.

Together with Einstein, whom we had met before during his stay at Leyden early in 1911, Ehrenfest called on us. (At that time my husband was assistant to Professor du Bois at his private laboratory in Berlin.) This visit was the beginning of a life-long friendship with both of them, a friendship which belongs to the most precious memories of our lives. Ehrenfest told us later how excited

¹⁾ Phys. Z. 8 no. 9, 1907.

²⁾ Begriffliche Grundlagen der statistischen Auffassung in der Mechanik. Encyklopädie der Math. Wiss. IV 2 II, Heft 6 D.

he had been when he received Lorentz' first letter telling him of the proposed call to Leyden. How great an honour and privilege to be selected successor to the first theoretical physicist of the period. Ehrenfest's admiration for Lorentz would increase throughout his life, and would grow into an affectionate veneration which would take in the whole of Lorentz' personality.

When Ehrenfest arrived in Leyden the difficulties which presented themselves were greatly eased by the manner in which my father helped him and soon showed him a warm friendship. In Ehrenfest the Leyden professors and students encountered a man quite different from anyone to whom they had been accustomed thusfar. A man free from traditions, not hampered or ruled by fixed social customs, he was the personification of a man who tried to find his own way through the difficulties which beset life and which are inherent in the association with others.

By reason of his friendly spirit he made every effort never to hurt or annoy anyone, whereas his wisdom led him to appreciate the practical importance of many of the habits and customs which he encountered at Leyden and which in the nature of the case were unfamiliar to him. And yet, it would happen that, in spite of all his efforts, due to misunderstanding he would offend someone; this then would lead to an estrangement between such a person and himself. But it was nearly always his very interest in people which would lead to such an awkward situation, due perhaps to a wrong approach to the problem. His intention was the very best, it was always an attempt to render aid, comfort or to show sympathy. Outstanding in his career was the great and fertile influence which he exerted in all things that touched his field of knowledge and scientific activity. Lorentz' expectations were fully

met; Ehrenfest's lectures were brilliant, clear and to the point.

Different from my father, his interest in the students in general, a few cases excepted, enabled him to put himself in their place, and to sense accurately which part of the lecture would present difficulties to them. These points were then brought to the foreground, "hervorgehoben", and were given extra attention. Do not think, on account of this one German word, that Ehrenfest did not lecture in our language. Quite the reverse, within a very short time after his arrival in the Netherlands he began to lecture in Dutch, although imperfectly. Ehrenfest was no linguist, but he did have the gift of expressing himself clearly, often with the aid of words borrowed from foreign languages, sometimes through gestures with his hands; and then again he would resort to drawings.

One may say that Ehrenfest was the founder of the physics colloquia in the Netherlands. He himself conducted the Ehrenfest Wednesday evening colloquium during almost twenty years, and kept it on a very high level. Under his masterly and enthusiastic leadership the "springende Punkte" (main points) in the discussions were brought to the foreground. Who from among the audience does not remember Ehrenfest's "und jetzt springt der Frosch ins Wasser", instead of the tame Dutch expression "en nu komt het er op aan"? And then something would follow which it was well worth remembering.

His faithful audience consisted of all kinds of people: there were candidates for the degree in physics who had already passed their examinations, former pupils of Ehrenfest's, young physicists from different neighbouring towns, and one could always expect a few colleagues, and finally the foreigners who came to visit Ehrenfest in Leyden. The

latter indeed came in increasing numbers, with the result that a new era dawned in the life of the University. These visitors were often invited to deliver lectures at the colloquium. Whenever Ehrenfest suspected that the lectures would prove too difficult for the younger ones among the audience he would anticipate these difficulties either with an explanation given in the course of his usual lectures, or on a previous Wednesday evening. This colloquium still exists, but alas, its founder and first eminent leader died too soon.

A second institution founded by Ehrenfest was the reading room Bosscha¹). This proved to be very useful, and he earned with this the gratitude of the physics group in Leyden, and particularly of the students. This room still exists, although some changes have been made, which, one fears, might have earned the disapproval of the founder, but which were probably demanded by conditions as they later developed. The reading room was originally housed in the small building which in 1906 was equipped for Lorentz (see page 98). In the first years of Ehrenfest's professorship this small structure was enlarged and better fitted out; a large lecture room was added and also a smaller one, better arranged for the purpose; in addition to these library rooms were provided. In 1954, shortly after the appointment of Lorentz' third successor, this building has been made over again and completely separated from the physical laboratory. It received then the name of "Instituut-Lorentz voor theoretische natuurkunde." Since 1932 the laboratory was called "Kamerlingh Onnes Laboratorium".

¹) By reason of the friendly relations of Lorentz with the Bosscha family, one of the sons of the old Professor Bosscha donated the funds for the library.

How great a difference between Ehrenfest and Lorentz as regards their relationship to their students and the influence which they exercised upon them! Whenever Ehrenfest met a young man in whom he saw great possibilities as far as physics was concerned, but who spent too much time and energy on other things, he would spare time nor effort to influence him to take up the study of physics seriously. Lorentz, facing the same situation, would regret the fact, but would come to the conclusion that, for better or for worse, this young man was more interested in other matters than in physics, and that this was his own business. Only when a student asked for help, or was in need of his assistance, on account of illness or similar circumstances, would Lorentz be ready to offer help.

What, thus one asks oneself, was the reason for this attitude? Was it a disinclination to meddle in the lives of others, due to a natural timidity, or was it a desire to save his energy for what seemed most important to him, his own creative work? I think it was a mixture of both. As for Ehrenfest, he too was led by the desire to employ his gifts and his energy in the most satisfactory and useful manner. He, as well as Lorentz, was aware of his own great gifts. He too considered creative work important above everything. It was alas not granted to Ehrenfest to do important creative work; like Lorentz he was completely honest both with regard to his own accomplishments and to those of others. And this was the reason why many a spiritual child was allowed to die before it was born. Both men were great, as few others, in their honest, disinterested service of science.

Ehrenfest venerated Lorentz for his creative work, and he admired him for his straight-forward character. He

was attached to him in a manner seldom witnessed between two persons. He was brokenhearted by Lorentz' death. He himself passed away five and a half years later, too soon and deeply mourned by all of us (September 25th 1933).

H. A. Kramers became Ehrenfest's successor. When he died in 1952 he was succeeded by S. R. de Groot.

SOLVAY CONGRESSES

Since my father's first trip to the United States his fame rose steadily and (I am quoting Professor Fokker) his opinion gained greater and greater authority. His personality grew in stature, and in all countries scientists were amazed at the all-encompassing breadth of his understanding and at the ease with which he was able to explain subtle points. Conspicuous also was his gift of anticipating questions which might arise, having his answers ready before the questions were put to him. Add to all this his well-balanced character, his tact in meeting people, the possession of which one might call a diplomatic gift, which enabled him to resolve differences sure to arise during large conferences, and last not least his perfect knowledge of modern languages, and it becomes abundantly clear why he was not only a welcome member of international scientific conferences, but that inevitably he became the natural leader.

When the Belgian prominent industrialist Ernest Solvay made plans for the organisation of regular "Conseils de physique et chimie" at Brussels, he invited H. A. Lorentz to prepare and lead those gatherings, where various actual scientific problems would be taken under consideration by a selected group of physicists. My father did this with much pleasure and great devotion and he was the very

soul of the Solvay congresses over which he presided. These took place in the years 1911, 1913, 1921, 1924 and 1927.

In an article by Marcel Brillouin, entitled "M. H. A. Lorentz en France et en Belgique, Quelques Souvenirs", which appeared in the "Nederlandsch Tijdschrift voor Natuurkunde" of January 1926 on the occasion of the fiftieth anniversary of Lorentz' doctorate, these congresses are mentioned. After the opening sentences: "Il y a eu, cette année, vingt ans que M. H. A. Lorentz répondant à l'appel de la Société de Physique, est venu se faire entendre pour la première fois des Physiciens français, en mars 1905. Du premier coup, nous fûmes séduits; et depuis lors la séduction ne fait que croître. Et d'abord quel émerveillement d'entendre un étranger parler notre langue avec une telle perfection, de forme et de fond..."; thereafter we read: "La connaissance et la pratique de la langue anglaise et de la langue allemande, permettent à M. Lorentz de saisir, dans tous ses replis, la pensée des interlocuteurs, et d'y répondre avec la précision la plus nuancée. Et il semble, qu'il soit infatigable, malgré le passage d'une langue à l'autre dans la discussion des théories et des hypothèses les plus éloignées en apparence des notions classiques. Ceux qui ont eu le privilège d'être conviés à ces mémorables séances "Sur la théorie du rayonnement et les quanta" (1er Conseil Solvay 1911) gardent le souvenir de l'action incessante du président, empêchant la discussion de s'égarer après l'avoir organisée par une excellente répartition des rapports entre les théoriciens et les expérimentateurs. Sur un sujet si déconcertant, il y a vingt ans, comme il était à craindre que la petite salle de l'Hotel Métropole devint un véritable Babel! Mais Lorentz suivait tout, arrêta le conférencier quand son exposé, un peu difficile à saisir, paraissait

échapper à quelqu'un d'entre nous, et en reproduisant l'essentiel, filtré par sa claire intelligence, dans les deux langues nationales des autres congressistes. Et chacun pouvait suivre sans difficulté — mais non sans une attention soutenue — les thèses et antithèses, les arguments et les objections, et surtout dire ce qu'il ne comprenait pas et obtenir des éclaircissements plus ou moins satisfaisants”.

And then Brillouin describes to us how the beloved chairman tirelessly tried to promote pleasant relations among the members of the conference. “Au second Conseil Solvay¹⁾ pendant 1913 de nombreuses petites tables avaient été installées dans une salle voisine de celle des séances et un lunch froid, copieux et délicat, était servi vers une heure aux congressistes. Réunissant à sa table tantôt un groupe, tantôt un autre, M. Lorentz établissait un lien d'intimité cordiale entre ceux d'entre nous qui se rencontraient pour la première fois. D'ailleurs à aucune table la discussion ne chôlait”.

“Extrêmement sobre et actif, M. Lorentz au moment du café et du cigare commençait à circuler de table en table, activant les conversations jusqu'au moment où, après quelques pas dans le parc, il nous rappelait tous à l'œuvre”.

“La seule invitation que M. Lorentz acceptait pour nous était le somptueux repas de clôture présidé par M. Ernest Solvay ou par M. Armand Solvay²⁾, tous travaux terminés; c'était à la fin de ces repas que j'ai admiré le merveilleux art de dire tout ce qu'il fallait dire expressément, d'indiquer seulement, ou de taire tout ce qu'il convenait de laisser dans une ombre discrète sans jamais dire

¹⁾ Depuis 1913 dans une salle de l'Institut de Physiologie, fondé par M. Solvay et situé dans le parc Leopold.

²⁾ Son fils.

un mot inexact, ou même trop adroit, en vue de ménager de très légitimes susceptibilités”.

And he finishes with the words: “Pour exprimer le sentiment intime de tous les Français et de tous les Belges, qui ont eu le plaisir d’approcher M. Lorentz, deux mots s’imposent: affectueuse admiration pour son œuvre admirable et pour son beau caractère”.

Many a reader will ask: Why was it that Lorentz with his love for undisturbed study gradually began to interest himself in the international world of his colleagues, and to do this with pleasure and devotion? Had his work in his own study ceased to be his chief attraction, or was it a source of satisfaction to him to participate in the further elucidation of current ideas among the prominent physicists of the world? The first unquestionably was not the case. And surely the value which he attached to serious study undertaken by single individuals had not decreased. We merely need to read the words with which he opened the first Solvay Congress in 1911: “Quel sera le résultat de cette assemblée? Je n’oserais le prédire, ne sachant pas quelles surprises nous sont réservées. Mais, comme il est prudent de ne pas compter sur ces surprises, j’accepterai comme très probable, que nous ne contribuerons que peu au progrès immédiat. En effet, le progrès de la science se fait plutôt par l’effort individuel que par les réflexions faites par un congrès ou par un conseil, et même il est très possible que, pendant que nous discutons un problème, un savant solitaire en un autre endroit du monde en trouve la solution”.

INFLUENCE UPON EDUCATION

We shall return to the Netherlands in order to see how much this country in the first place has profited by what

Lorentz accomplished outside the field of pure science. Let us consider education first of all.

My father achieved a great deal in this field, and every-one of his actions bore testimony to his original and idealistic mind. I mentioned already on page 42 the founding of a physical laboratory (1883) for first year medical students. For medical students too it is of great value to work out some problem and to solve it experimentally. This was the fundamental idea of the new laboratory. In later years my father became interested in education as carried out in the grammar schools and the secondary schools. He was one of the founders of the first Lyceum in the Netherlands, the "Nederlands Lyceum" in the Hague, of which he was curator for many years. My father had known its first rector, Dr. Casimir, for a considerable time. Dr. Casimir had studied philosophy with Professor Heymans in Groningen¹⁾. During his college years he also showed interest in mathematics and he had read Lorentz' text book (see page 84) on differential and integral calculus. In this connection he had asked the author to explain some difficult points. My father was touched by the great interest shown by this intelligent amateur, and thus a tie was formed between him and young Casimir. Lorentz greatly valued this young man, whereas Casimir felt admiration and affection for my father. A touching proof of this is found in a short article written by Casimir on the anniversary of my father's death in 1939. It is one of the most genuine expressions of appreciation which has ever come to my attention. What a pity that it has been published only in a weekly paper which was not widely distributed²⁾.

¹⁾ Later he became Doctor honoris causa at Gent.

²⁾ The "Hollandsch Weekblad" of February 4th, 1939.

SOLVAY CONGRESS 1921



Front row (l. to r.): A. A. Michelson, P. Weiss, M. Brillouin, E. Solvay, H. A. Lorentz, E. Rutherford, R. A. Millikan, Madame Curie
2nd row: M. Knudsen, J. Perrin, P. Langevin, O. W. Richardson, J. Larmor, H. Kamerlingh Onnes, P. Zeeman, M. de Broglie
3rd row: W. L. Bragg, E. van Aubel, W. J. de Haas, E. Herzen, C. G. Barkla, P. Ehrenfest, M. Siegbahn, J. E. Verschaffelt, L. Brillouin

SOLVAY CONGRESS 1927



Front row (l. to r.): I. Langmuir, M. Planck, Madame Curie, H. A. Lorentz, A. Einstein, P. Langevin, Ch. E. Guye, C. T. R. Wilson, O. W. Richardson

2nd row: P. Debye, M. Knudsen, W. L. Bragg, H. A. Kramers, P. A. M. Dirac, A. H. Compton, L. V. de Broglie, M. Born, N. Bohr
3rd row: A. Piccard, E. Henriot, P. Ehrenfest, Ed. Herzen, Th. de Donder, E. Schroedinger, E. Verschaffelt, W. Pauli, W. Heisenberg, R. H. Fowler, L. Brillouin

Missing: W. H. Bragg, H. Deslandres and E. van Aubel

When Casimir later occupied the Chair of Pedagogy at Leyden University, Lorentz was one of the curators of this chair (Professor Dr. H. B. G. Casimir, the theoretical physicist, is the son of Professor Dr. R. Casimir).

My father was also very interested in the education of young people in modest financial circumstances. Thus, it was largely owing to his initiative that in 1910 in the city of Leyden one of the first free libraries was founded.

In the matter of education Lorentz accomplished his most important work at the Board of Education. Since its foundation in 1919 he was a member, and since 1921 he was President of the Department of Higher Education, as a successor to Bavinck. Lorentz and van Vollenhoven, Professor of Law at Leyden, are largely responsible for the creation of a new Academic Statute, after long and tedious conferences. The new arrangement of examinations at the Universities clearly shows the influence of my father's mind.

The second great work which the Board of Education accomplished under the leadership of Lorentz (1924) was an arrangement which aimed at a more satisfactory distribution of the professorial chairs among the various Universities, than had been the case till then. This was a difficult task because one had to reckon also with the Chancellor of the Exchequer. In 1926 my father was forced to resign his post at the Board of Education on account of too many other duties which took up his time.

LORENTZ AND THE PEACE MOVEMENT

As was to be expected Lorentz' activities and his influence did not remain confined to his own country. In 1909 he was appointed President of the Department of Physics of the "Koninklijke Akademie van Wetenschappen". In

this function, which he continued until 1921, a mighty influence emanated from him towards moderation and consideration. How plainly this influence showed itself during the first world war and the years following it.

The same outstanding position which Lorentz had come to occupy in the Netherlands in the course of life, now became his also outside his native country. He always tried to make his influence serve the creation and maintenance of good international relations in the field of science, as well as in all other respects. As early as January 1913, when the minds and hearts of the people in Western Europe had not yet been shocked by the horrors of a war which was soon to break out (1914-1918), we find a short article written by Lorentz, in a special number of a periodical issued by the Nederlandsche Vereeniging "Vrede door Recht" (Dutch Society "Peace through Justice"), which was dedicated to the peace movement. The existence of this society is proof that in certain circles in the Low Countries the possibility of war in Western Europe had already been considered, on account of the friction existing between the great nations. It is no wonder that my father, with his sense of justice, his aversion to war and his respect for the individual, had become a member of this organisation. A citation from the article just mentioned may follow: "It is indeed certain that the knowledge of participating in a serious common task which calls for the highest efforts should turn one against the dissipation of energy in a needless conflict. Who would not acknowledge that cooperation and the pursuit of the same goal will create in the long run a precious sense of mutual appreciation, solidarity and good comradeship, which will promote peace".

Just as Lorentz in his dissertation pointed out the direc-

tion which he intended to follow with regard to his scientific work, likewise, in the few lines quoted above, he indicated the path he intended to take as a member of society. Was the remarkable way in which both trains of thought ran parallel the cause of the rare harmony present in my father's life, or was it the result of this very harmony? Until the end of his life Lorentz would also pursue this second path. The last letter written by him was addressed to Millikan and dealt with ways of promoting the peaceful co-operation of all peoples.¹⁾ Before finishing this letter, his very last effort, my father was forced to stop on account of a high fever which resulted in his death.

Haarlem, January 20, 1928

Dear Millikan,

As you know already, we have been glad to accept the offer of the American national committee on intellectual cooperation; indeed, the enquiry which we are asked to make falls entirely within the scope of our commission. Dr. Picht will be able largely to devote himself to it for a ~~long~~^{certain} time and I expect him here one of these days, so that I may have a talk with him about the details.

¹⁾ One may find this letter, together with other correspondence, in the "Rijks-Archief" at the Hague.

INTERNATIONAL SCIENTIFIC RELATIONS

In order to give an impression of my father's activities in the field of international relations a page from the address, delivered in Arnhem by Professor Dr. A. J. Kluyver, January 1953, will follow:

"Everyone reading this article) will understand how deeply shocked Lorentz was when the war broke out. Soon all his efforts were directed towards the restoration of an international basis of scientific co-operation, so sadly disturbed by the war. There was a great difference of opinion about this matter among the Dutch scientists, which also became evident in the "Akademie". On the one hand several of the leading men were of the opinion that science ranked too high above the quarrels of governments and nations than that existing scientific relations should ever become affected by the prevailing unfortunate conditions. Others on the contrary believed that the scientists of some of the warring nations had so degraded the ideals of scholarship that discrimination against them was unavoidable. These diverging opinions showed their practical consequences shortly after the war.

"The allied conquerors decided to create an entirely new set of international scientific organisations, the participation in which was restricted to the conquering nations, and to those neutral nations wishing to join. The scholars of the Central nations were excluded. The question arose as to which stand the Dutch scientific world should take. With firm conviction, great vigour and much tact Lorentz, of the opinion that the Netherlands should join the new organisations, was able to gain his point against strong opposition on the part of some scholars against Dutch

) The above mentioned article in "Vrede door Recht".

participation in a worldwide organisation, which knew no barriers. He was led above all by the consideration that only by taking this attitude the Dutch might hope to exercise their influence abroad towards restoration of the universality of science. With remarkable zeal Lorentz continued to struggle for the accomplishment of this purpose.

“Those who, like the present speaker, were privileged to listen to Lorentz’ eloquent and touching pleas at a meeting of the “Conseil International de Recherches” in Brussels on July 7th, 1926, will never forget those moments. True, the Dutch-Danish proposition relating to this matter was not accepted in this session, on formal grounds, but the minds and hearts of those present had been won over, and the next meeting of the conference revealed an entirely different attitude regarding this matter”.

COMMISSION INTERNATIONALE DE COOPERATION INTELLECTUELLE

Then Professor Kluyver continues: “In the meantime Lorentz found the opportunity to expand his efforts on a higher level, and to advocate the proposition that, in a spiritual sense of the word, a supernational status should be assigned to science. In 1923 he was asked to become a member of the “Commission Internationale de Coopération Intellectuelle” of the United Nations. This committee consisted of only seven of the most eminent scholars of the world; its first President was the philosopher Bergson. When the latter was forced to resign on account of ill health, Lorentz became his successor”.

The “Assemblée de la Société des Nations” was subdivided into several committees. All of the nations who had joined were allowed to participate in each one of those committees. Of the 49 nations 47 were represented in the

second committee (Organisations techniques) of which the "Commission intellectuelle" formed a part. In 1925 the French government had given the committee a seat in Paris, "l'Institution internationale de coopération intellectuelle". In 1926 this institute was opened officially.

The following lines represent parts of a report of the ceremony (Nieuwe Rotterdamse Courant, 17/1, 1926).

"The most vivacious, most humorous, most important, and surely the most applauded speech delivered at the opening of the "International Institute for intellectual co-operation" came from Professor Lorentz, acting as President of the International Association for intellectual co-operation. In contrast to what happened in the case of the other speakers, who addressed the meeting in their official capacity, a loud applause arose when Lorentz took the speaker's chair. When he had finished the applause became almost an ovation, in which the President of the French Republic joined. The hall was filled with diplomats, artists and scholars.

"If at first doubt existed whether or not the committee of prominent scholars would be able to handle the problems connected with the international political situation, this ovation proved convincingly that, as far as the President was concerned, this fear was without ground".

On September 8th, 1927, in the 8th "Session ordinaire de l'Assemblée de la Société des Nations" at Geneva, the "Commission internationale de coopération intellectuelle", presented a report to the "Second Committee", concerning the work done under its direction in the "Institut international" at Paris. This report was preceded by an introductory speech delivered by its President, Professor Lorentz.

Many people attended this meeting, among others

Jhr. Mr. W. J. M. van Eysinga, Professor emeritus of the Leyden University, who represented the Netherlands in the "Société des Nations" as member of the first committee (Questions constitutionnelles et juridiques) and as president of the fourth committee (Questions budgétaires et financières).

He writes: "The committee as well as the entire numerous audience listened with rapt attention to the clear statement made by the successor of France's great philosopher Bergson. One was immediately conscious of the fact that here a man was speaking who had mastered his subject completely, and who in fact had risen above it. And one was all the more impressed by this fact because Lorentz had stated that at first he had not clearly envisaged the direction in which the organisation should move. However, he had not hesitated for a moment to follow the call of the Council of the League of Nations. Apparently he had grasped, within the shortest possible time and with the rapidity of thought so characteristic of him, the essential obligations which he in his capacity as President would have to meet. Lorentz explained in a masterly fashion the aim of the organisation and he pointed out the method it should use in order to bring about spiritual co-operation. Finally, he gave an account of the specific subjects which were being considered. Co-operation was needed in the same sense in which it had existed already before, as he showed by an example borrowed from the past, in proof of the fact that in the long ago the great minds did work together within the field of physics. The present organisation should again, thus Lorentz reasoned, consider international co-operation as one of its chief aims. Lorentz lifted the idea of co-operation to a higher level when he said that the younger generation too ought to

realise that "la coopération intellectuelle doit être la méthode normale de conduire les affaires du monde". In this respect as well, the address has lost nothing of its actuality.

The speech made a profound impression: the French-Canadian chairman Danduran was the spokesman for the entire committee when he thanked the speaker most warmly for his address¹⁾".

My father's influence upon matters outside of his own sphere of activities was remarkable indeed. Here too, of course, his prestige rested in part on his great fame as a scientist.

His most permanent influence however Lorentz gained through his scientific work and its many applications in modern technical concerns.

In the following address Professor Dr. Balth. van der Pol writes about these applications.

¹⁾ This address was published in the "Journal Officiel de la Société des Nations" (1917), Supplément spécial no. 56. Procès-verbaux de la deuxième Commission de l'Assemblée (organisations techniques), page 10.

H. A. LORENTZ AND THE BEARING OF HIS WORK ON ELECTROMAGNETIC TELECOMMUNICATION

BY

BALTH. VAN DER POL

The purpose of this note is to draw attention to Lorentz' personality and achievements and to the bearing of his work on the theory of electromagnetic telecommunication.

With one great exception, Lorentz never tackled any directly technical problem. His work concerned theoretical physics, and as such has many applications to electromagnetic telecommunication. Moreover, much of it is so classical that, in modern times, one is apt to forget that he was the originator of several ideas which are of daily use in our communication technique.

When glancing over the long list of his publications, one is struck by the fact that he fertilised nearly all those parts of theoretical physics, which, in his lifetime, had reached a certain state of provisional maturity enabling them to be worked out theoretically. Thus we find many fundamental contributions from his pen in theoretical mechanics, thermodynamics, hydrodynamics, kinetic theory, theory of solid bodies, light, heat and general wave propagation. But perhaps his main work concerned the

electromagnetic field, the theory of electrons and relativity theory.

Lorentz' work and its bearing on the theory of electromagnetic telecommunication date back to his doctorate thesis, which he wrote at the age of 22. The subject is the theory of the reflection and refraction of light from the point of view of Maxwell's equations. Maxwell had shown that his equations proved the electric nature of light waves. However, at the time that Lorentz wrote his thesis (1875), there were still several competing theories. Lorentz definitely concludes that "On the basis of researches on the reflection and refraction of light, Maxwell's theory is to be preferred". The formulae deduced there, at a time when there was no radio, form the basis of all subsequent work in radio on the reflection and refraction of electromagnetic waves, for instance by the earth.

Lorentz concludes his thesis with the following sentence: "Far from having taken final shape, Maxwell's theory still requires the elucidation of many obscure points of which only a quite inadequate explanation can be given at the present time. But one of the interesting aspects of any progress we make in our knowledge of nature is the fact that it clearly shows what remains to be achieved and points out the direction that should be taken by future research if it is to be successful".

These sentences, which are of a visionary nature, and which were written at the age of 22, contain the germ of most of his later work on the theory of electromagnetism.

The main difficulty actually left by Maxwell was the impossibility of explaining on the basis of his theory light spectra such as those emitted by several chemical substances. It is here that Lorentz penetrated the problem

and tried to clarify matters. In Maxwell's time, what we now call the dielectric constant and magnetic permeability were regarded as overall properties of matter that could be measured statically or with slowly varying fields. But no insight into the reason why different substances showed different constants was available, or why these "constants" varied so much with the frequency of the waves. It is here that Lorentz postulated as early as 1878 the idea that the propagation of electromagnetic waves through ponderable matter was governed by small electrically charged particles in the substances. Lorentz subsequently worked out this fundamental idea in all its details and thus created the *theory of electrons*. He did this originally with a view to a better understanding of how short light-waves are propagated through ponderable matter. However, these theoretical results also clarified many properties of longer electromagnetic waves such as are nowadays used in radio communication.

For instance, the forces in an electromagnetic field acting on electrons, and therefore their motions, were fully worked out and crystallised in a set of mathematical equations which can be considered to be a development and elaboration of Maxwell's equations: e.g. the force acting on an electron moving in a constant magnetic field could be calculated. These formulae still form the basis of the working of modern magnetrons as used in radar and other short-wave communications; and also of modern cyclotrons which are used extensively for nuclear research.

The idea that the mass of an electron is partially or wholly of an electromagnetic nature was also elaborated by Lorentz.

In Leyden in October 1896, Zeeman published the

results of his experiments. He placed a light source, such as a sodium flame, in a strong magnetic field and found that the spectrum lines were slightly broadened or displaced, showing that the frequency of the emitted light had changed slightly on account of the presence of the magnetic field.

At the time of Zeeman's discovery, Lorentz had already completely developed his theory of electrons. Thus with the aid of his theory Lorentz could at once deduce from Zeeman's experiments the ratio e/m between the charge and the mass of the electrons vibrating in the sodium flame. This ratio was found to be of the order of 10^7 in C.G.S. units. He could also predict the state of polarization of the emitted light, which Zeeman immediately found confirmed.

In October 1897, another great physicist, Sir J. J. Thomson, in Cambridge, England, published the findings of his experiments where he reflected elementary particles produced in discharge tubes with the aid of electric and magnetic fields; in this way he also obtained numerical values for the ratio of the mass and the charge of his particles. The fact that the ratio e/m found by J. J. Thomson was not far from the similar ratio which Lorentz' theory could deduce from Zeeman's experiment, showed that these particles were probably identical in the two widely divergent experiments. Thus the electron was born. It can therefore be said that the electron was independently *invented* by Lorentz in Leyden and *discovered* by J. J. Thomson in Cambridge. All three physicists, Zeeman, Lorentz and Thomson were, a few years later, honoured with the Nobel prize.

The present author is perhaps the only living physicist who had the great privilege of working with both J. J.

Thomson (from 1917 to 1919) in Cambridge and with H. A. Lorentz (1919-1922) in Haarlem. It would be very tempting to compare here the widely divergent personalities of these two great scientists. Thomson, on the one hand, designed his new experiments, I think, after an impulsive flash of inspiration. Lorentz, on the other hand, usually pondered long over his new ideas and their theoretical implications and he was only entirely satisfied if he could treat them from different aspects and use different methods all yielding the same result. Of course, along both lines, important progress may be achieved in science.

There are several outcomes of Lorentz' electron theory which have a direct bearing on modern radio technique. He showed in detail how to calculate the waves emitted from a harmonically oscillating electron free in space. The solution of this problem completely coincided with the theory which Hertz developed for an oscillating dipole, the current in Hertz' dipole being equivalent, according to Lorentz' theory of electrons, to the product of the charge of the electron and its speed. In both cases the same radiation resistance is obtained. It need hardly be stated here that this theory is at the base of all modern calculations of radiation from antennae.

There are two other parts of Lorentz' electron theory which have a bearing on (a) the modern theory of the ionosphere and (b) the atmosphere of the earth. When ponderable matter is brought into an electric field, if we wish to calculate the local electric field near one molecule, Lorentz showed that, in general, we also have to take into account the influence on this local field of the polarization of the neighbouring molecules. Thus he introduced a famous mathematical term in his theory of polarization. This term is, no doubt, needed in the case of crystals.

However, later on, it was felt doubtful whether this term had also to be considered in the field produced by electromagnetic waves in the ionosphere. Thus in the physical literature between 1929 and 1934 extensive discussions took place about the necessity of introducing this term into the theory of the ionosphere. The latest conclusion (C. G. Darwin) is that this is *not* the case, in view of the physical circumstances in the ionosphere. On the other hand, Lorentz' theory of polarization does enable us to calculate the dielectric constant of a mixture of gases when their densities and dielectric constants are known. A specific case is the atmosphere of the earth containing oxygen, nitrogen and water vapour. Here Lorentz' theory should be applied and it is at the base of modern research on the propagation of waves through the lower atmosphere.

Again, in 1892, Lorentz introduced "retarded potentials" which form the theoretical aspect of the fact that electromagnetic waves are propagated with the velocity of light. In the modern theory of Laplace transformation these retarded potentials appear quite naturally in the form of a "composition product".

We also find in Lorentz' works a clear and sharp statement of the following reciprocity theorem for linear systems¹⁾:

"If an electromotive force applied at a point P in the direction h produces in a point P' a current whose component in an arbitrarily chosen direction h' has the amplitude μ and the phase v , an equal electromotive force acting at the point P' in the direction h' will produce a current in P, whose component in the direction h has exactly the same amplitude μ and the same phase v ."

¹⁾ H. A. Lorentz, Proc. Acad. Amsterdam 7 (1905) 401.

This theorem is of a very wide generality. It has been applied with much success in practice for finding the optimum site of a radio transmitter to ensure that at two points, where it is difficult to provide a good service, optimum conditions may be obtained.

This certainly is the place to refer to one of Lorentz' last papers where he develops a generalisation of a little known remark, also of very general validity, by Oliver Heaviside¹⁾, concerning electric networks. As I had occasion to conclude from many personal conversations, Lorentz had a great admiration for the work of Heaviside. Heaviside's theorem can be worded as follows:

"Given a constant passive network at rest. If at time $t = 0$ suddenly a constant E.M.F. is applied to the network, in general transients will occur. After a long time, say $t = t_1$, the transients may be considered to have died down and a direct current only will in general be present in the network. This direct current (if there is any) will cause a Joulean heat dissipation at a constant rate per second. If we call W' "the pseudo heat dissipation" which would have occurred if the constant, final, current had been present all the time from $t = 0$ to $t = t_1$, Heaviside's remark is to the effect that, when the steady state has been reached, the total amount of work A done by the E.M.F. exceeds the "pseudo heat dissipation" (if there is any) by twice the excess of the electric energy U over the magnetic energy T , or

$$A - W' = 2(U - T)''.$$

A remarkable consequence of this remarkable theorem is that a condenser can be charged from a D.C. source with an efficiency of 50% only. As stated, Lorentz gene-

¹⁾ O. Heaviside, Electrical Papers II (London 1892) 412.

ralised this already general theorem of Heaviside so that it also became applicable to electrical systems with distributed capacitances and inductances. It is further of interest to note that in this paper, Lorentz introduced impressed *electric* as well as impressed *magnetic* forces into the Maxwellian equations. In ordinary circuit theory they correspond to an electromotive force and current source respectively.

Although during the last twenty-five years physics has made enormous strides, opening up many new avenues, Lorentz' work will remain for all times a masterpiece of classical physics, much of which is still being applied daily in various branches of modern electromagnetic telecommunication technique.

ENCLOSURE OF THE ZUIDERZEE

BY

J. Th. THIJSSÉ

Lorentz lived in a country a considerable part of which is below sea-level. In the course of the centuries many floods have occurred there. They have caused serious loss of life and property.

In January 1916 a severe flood struck the North of the country. The sea walls around the Zuiderzee failed in two places and great parts of the province of Noord-Holland, north of Amsterdam, were flooded. Amsterdam itself had a narrow escape: a dike near the town was saved from breaking only by a desperate effort.

As a consequence of this disaster the decision was made to construct a dam across the northern part of the Zuiderzee, thus pushing the sea back over a distance of about fifty miles.

This project was not new. For centuries it has been realised that important advantages could be obtained by closing off the Zuiderzee. More than a hundred miles of dikes around it, mostly built on unstable soil, would be reduced to a second line of defense. Their task would be taken over by the enclosure dike, only twenty miles in length, traced over places where the foundation is good. This dike would also offer a short connection for the

traffic between the north-western and north-eastern parts of the country. Considerable parts of the bottom of the Zuiderzee south of the dam consist of fertile soil, very well suited for agriculture. These parts were to be reclaimed by surrounding them with secondary dikes and the remainder could gradually be converted into a freshwater basin, the IJssel Lake, large enough to supply the surrounding land with fresh water during dry summers.

There were disadvantages too, however. The important herring and anchovy fishery would have to disappear and nobody knew to which extent it would be replaced by fisheries in the freshwater lake.

Another disadvantage was put forward by people living around the remaining northern part of the Zuiderzee. They predicted that the sealevel reached by storm surges in that part would be higher after the construction of the enclosure dike than it was before.

It is easy to see that this view is correct. The connection between the North Sea and the Zuiderzee consists of narrow gaps in the string of "Wadden Islands". When a surge in the North Sea strikes the islands the Zuiderzee can only be filled slowly. Before an equilibrium has been reached the storm is over and the levels reached in the area south-east of the islands are relatively low. After the enclosure the above area is reduced to about one third of its original size and therefore the process of filling will be sped up. Before the gale has ended, higher levels will have been reached in the remaining part, which was named "Waddenzee"¹⁾.

It is difficult, however, to calculate the amount of the rise. The lowest value mentioned in a publication for the

¹⁾ The local name for shoals or sand flats is "Wadden". The Waddenzee (= Wadden sea) consists of shoals intersected by deep channels.



maximum (which would evidently occur in the south-eastern corner of the Waddenzee) was six inches. Other evaluations varied up to more than twelve feet. As the dikes around the Waddenzee had to be raised accordingly, which could involve considerable expense, it was important to find an accurate figure.

When, in 1918, the bill stipulating that the Zuiderzee should be enclosed and partially reclaimed was discussed in Parliament, it was resolved that the question should be thoroughly looked into. A State Committee was appointed in order to take the matter in hand. It consisted of engineers, oceanographers and meteorologists. An appeal was made to Lorentz to preside the committee.

It must have been difficult for Lorentz to make up his mind whether he should accept this post or not. On the one hand he had other important work to do and he realised that the Zuiderzee-study would take up a considerable amount of time. On the other hand, it is the duty of every Dutchman to contribute to the best of his ability to the never ending battle against the sea.

Lorentz' contribution has been most important. The study proved to be very difficult, and the final report was not presented to the Queen until November 1926.

Evidently the study had to be based on observation of the existing condition. Fortunately, continuous records of the sealevel, extending over a great many years in many places, were available. They included about fifty storm surges.

But more was needed. Levellings had to be made in order to determine the plane of reference of the tide gauges in the islands. This involved crossing the gaps between the mainland and the islands, which was not a simple operation. North of IJmuiden no tide gauges

existed on the coast of the North Sea. Every gauge in this region was inside the string of islands and therefore more or less influenced by the Zuiderzee. New gauges had to be installed along the open coast, far from the tidal inlets. The coast itself consists of a flat sandy beach; the observations have to be made in the surf which can be violent during a gale. Special equipment had to be developed to get reliable results in these places.

Another gap in the basic material was the absence of current readings. Expeditions were sent out by the Committee to complete our knowledge in this respect.

These observations were organised by the engineering section of the Committee, led by vice-president Dr. Wortman, who was to be the General Director of "Zuiderzee works". Nevertheless, Lorentz himself had an active part in this. One of my first impressions of Lorentz dates from the trials of one of the electric gauges for the North Sea shore at the works where they were manufactured. He was very much interested in the construction, and the remarks and advice he gave showed that he might have been a first-class engineer instead of a great physicist.

In the meantime the publications concerning the problem were critically examined. There were several of them, approaching the problem from various angles. Apart from statistical methods two distinctly different methods could be distinguished: the oceanographic method and the engineering one.

Oceanographers had a thorough grasp of non-permanent phenomena, but the frictional resistance of the currents over the rough bottom of the shallow sea was an unsurmountable barrier. For the civil engineers, on the other hand, friction was common practice, but their difficulties began when a considerable portion of the acting

forces was used for accelerating the water masses apart from overcoming friction. The fundamental equations of continuity and of movement were well-known of course, but their application to the penetration of the tides and of the storm surges through the intricate network of channels and over the sand flats was not feasible.

In the spring of 1920 Lorentz decided to take the normal tides in hand first. At low tide the shoals are uncovered and at high water they are submerged a few feet only. The currents are mainly confined to the deep channels, where the direction of the current coincides with that of the channel. Cross currents are negligible.

Now the fundamental equations for waves in a channel can be applied. Lorentz simplified these equations to such an extent that only two, linear, equations remained. The main factor in this was the substitution of the force of frictional resistance, which is roughly proportional to the square of the velocity of the current, by a hypothetical force which is assumed to be proportional to the velocity itself. The factor of proportionality was determined by the condition that the work done by the hypothetical force throughout a tidal period shall be equal to the work which is done in the same period by the real frictional force. This assumption was checked for a case in which integration is also possible with the quadratic resistance: the damping of oscillations of a fluid in a U-tube¹⁾.

It is clear that by means of this simplification it is possible to calculate the speed of propagation and the attenuation of a wave passing through a channel, but not the deformation of the wave, viz. the formation of higher harmonics. There is no sense in applying the method to the complicated tides occurring in the North Sea near our

¹⁾ "De Ingenieur", 36 (1922) 695.

coast; the main harmonic purely sinusoidal component, the principal semi-diurnal lunar tide M2 of the oceanographers, was taken instead.

This was the beginning of a period never to be forgotten. I had the honour and the pleasure to test the new method, to develop it and to apply it to the Zuiderzee and to the Waddenzee. Nowadays the calculations may appear simple, but thirty-five years ago a civil engineer had to wrestle with the problems — not always successfully. In one of the letters which I received from Lorentz during this period, he wrote: "The origin of your difficulties is the fact that you made a series of errors". It was always a pleasure to have one's mistakes pointed out by Lorentz. It was never obvious that he tried to spare the feelings of the other party. Nevertheless he was very considerate. I never minded if during a discussion in Lorentz' home in Haarlem it turned out that the work of many days had to be rejected and that I had to start all over again.

But Lorentz himself did mind. Once — during a later stage — I found that he had started a calculation himself in order to save me the trouble of correcting an error. He even handled a slide rule, the instrument of the engineers, which he had never used before, of course. Fortunately I could persuade him to leave the actual calculations to me and to devote as much of his time as he could to Solvay congresses, quantum mechanics, and visiting professorships in the United States. We always had a guilty conscience that we kept him away from these important activities.

The calculations were checked first by applying them to simple cases, like the Gulf of Suez. Starting from the harmonic tidal constants at Aqaba it proved to be possible to calculate correctly the constants observed at Suez.

A more severe test was found in Bristol Channel, a classical area in which the amplitude of the tidal wave increases towards the end of the funnel. There the tides are among the highest of the world. In this case the difficulty is the variation of the depth during a tidal period. At low tide the shoals are dry or nearly so, at high tide they are covered by some forty feet of water. The simplified formulæ assume a constant depth, which is far from true. The average between the depths at high and at low tide was introduced and the result was surprising. The computed phase difference between the principal harmonics of the tides at Lundy Island near the entrance of Bristol Channel and at the narrow end of the estuary (Chepstow), and the proportion of the amplitudes were exactly equal to the observed values. The agreement was almost too good to be true.

Higher harmonics are generated in Bristol Channel, of course, and these cannot be found by the "linear" calculation, but that was not its aim.

The method had proved its validity and now it could be safely applied to the network of channels which constitute the Zuiderzee. The first step was the calculation of the existing situation; the boundary conditions being the North Sea tides outside each of the inlets and the coastline of the Zuiderzee. The result was equally satisfying as in the former cases: the harmonic constants of the tides in the places corresponding with the tide gauges around the Zuiderzee and in the islands therein agreed in a fair way with the observed values. A very close agreement could not be expected as the actual Zuiderzee had to be schematised into a system of reactangular channels, bordered by shoals.

Now it was the time for a prediction. The border conditions were changed: the same tides in the North Sea,

but instead of the contours of the Zuiderzee those of the Waddenzee, reaching as far as the enclosure dam only. In accordance with expectations, stronger tides were found now than in the case of the open Zuiderzee. Along the enclosure dike the amplitude was nearly doubled.

There was an unexpected result as well: the strength of the currents through the gaps between the islands proved to be greater than before, notwithstanding the fact that the area inside the gaps was reduced to one third of the original value. I was in Lorentz' study a quarter of an hour after this result had been obtained, at my wits' end. Lorentz was surprised too and it took him nearly ten minutes to find the explanation.

It is a matter of interference between the tidal wave which penetrates from the North Sea into the Waddenzee and the wave which is reflected at the end of the estuary. In absence of friction this would result in a standing wave with a node — hence a strong current — at a quarter of a wave length from the closed end and an antinode — hence no current — at half a wave length from that point. On account of the friction the contrast is reduced; nevertheless there are in areas at a mutual distance of a quarter of a wave length alternately strong and weak currents. The length of the Waddenzee is about twenty percent of the length of the tidal wave, which is about 250 km. (160 miles) in these waters. The length of the former Zuiderzee, however, was slightly more than half a wave length. Thus the oscillation of the latter basin was maintained by relatively small impulses, given by rather weak currents.

In principle the explanation is simple, but in 1920 even the oceanographers had no clear insight in the tidal phenomenon of the Zuiderzee.

Strong tides mean a low level of low tide and this

means a great capacity of the sluices which are built to evacuate the surplus of water from the IJssel Lake into the sea. So the size of the evacuation sluices could be reduced because of the result of the tidal calculations. This saving of several millions of guilders was the first fruit of the activities of Lorentz' Committee.

Lorentz lived long enough to see some of the predictions confirmed. The first section of the enclosure dike through the Amsteldiep between the mainland of North Holland and the island of Wieringen, which was constructed in 1924, had a marked effect on the tides. This had been predicted by calculation: the agreement was almost perfect. Even the increase of the cross section of a channel near the Frisian coast by scouring, corresponded with the predicted rate of increase of the strength of the current in that channel.

Lorentz was not content to hear about the progress of the enclosure dike from others: several times he has been on board the motorboat which was used for measurements. In April 1924 he assisted with observations of the current over the foundation of the dam in construction. He enjoyed the ever imposing phenomenon of the tides: the current accelerating to its full force and then coming to a standstill again under influence of the adverse slope of the sealevel. But we also visited the cranes, the big bucket- and suction dredgers and watched the tough boulder clay being deposited in the body of the dam by dump barges and the revetting of the bottom by the sinking of willow mattresses, a special Dutch method of protecting the bottom from the scouring effect of strong currents. The visit to the Amsteldiep-dam was repeated in July. The construction of the dam had reached its critical stage then. The original cross-section had been restricted to a small

“closing gap”. The current in such a past gap is quite fierce and gets stronger as the gap is narrowed. It was even strong enough to break our anchor chain, an adventure which thrilled Lorentz very much.

By that time the tidal calculations had been considerably extended. They did not only cover the original conditions, before the construction of the enclosing dam had been started, and the final one, after closing the last gap in the dam, but also intermediate stages, with closing gaps in various places and of various widths. The whole plan for the construction was based upon the results of those calculations: the decision which sections should be built first and which had better be left to the last stage, the choice of materials to be used, the area of the bottom to be protected by mattresses against scouring, all kinds of precautions, all this depended on the work of Lorentz' Committee.

According to the original plan it would take nine years to construct the dam between the eastern tip of the island of Wieringen and the coast of Friesland. In reality the first load of boulder clay was dumped on January 20th, 1927, and the last gap was closed on May 28th, 1932: a saving of several years. This was due to a great extent to improvements in contractors' equipment, to a good organisation and the great devotion shown by everyone concerned, but it was equally important that we knew beforehand the effect of every move which was being made and what to expect in the next stage.

The third tour in the measuring boat was made in the beginning of September 1927. We crossed the Northern part of the future IJssel Lake, inspected the section of the dike which already reached above the water line, and the foundation pit, surrounded by an auxiliary dike, in which

a part of the evacuation sluices would be built. Naturally the current sweeping around the end of the dike was observed and, after passing the night on board, we went along the line where the enclosure dike is to-day.

It will not be necessary to say that Mrs. Lorentz accompanied her husband on these trips.

In 1921 a start was made with the calculations for the phenomena during a storm surge. It was evident that another method had to be found than the one which was used for the normal tides. Now the phenomenon was not periodical. Nor could we restrict ourselves to the general trend of the sealevel, such as is represented in the principal harmonic term: it was the highest peak we were after.

The whole burden of the struggle to find a feasible method which would yield reliable results fell upon Lorentz' shoulders. First he tried a generalisation of the harmonic method, but the quadratic frictional resistance prevented to reach our aim. Later a Riemann integration was tried, unsuccessfully too.

Not until 1925 the method was found that led to success.

The equation of movement and that of continuity, which express the water level h and the velocity of the current v in terms of the time t and the position in the channel s were expanded in power series of s . If h and v are known as a function of t for one point, $s = 0$, it is possible, with the aid of the series, to calculate the time-dependence of h and v at other points. The difficulty is that there is no place where both h and v are known. At the boundaries of the system in the North Sea, in a tidal gap, h is known but v is not. At the closed end on the contrary v is known (viz.: zero), but h is not. The only feasible way is the following. We assume v (as a function of t) in one of the tidal gaps and hope that the boundary

conditions at other points are satisfied. Naturally this is not the case and so the calculation has to be repeated with another shape of the v -curve: the result is only attained by trial and error and after a very great amount of work.

It is evident that a calculation of this kind with a complicated network of channels, closely resembling the actual Zuiderzee is out of the question. A very rough schematization to be adopted: the whole sea was represented by three channels only, starting from the centre of the enclosure dam: one to the main tidal inlet in the west, one to the tidal inlets in the north and the third down to the southern coast of the Zuiderzee. Two calculations were made: the first with the complete system, the second without the third channel: the latter represented the conditions after the enclosure.

The results of this calculation were compared with those of another one. Therein every channel and every shoal was taken into account, but another serious simplification was made: the flow was supposed to be permanent. In one situation the flow over the line of enclosure was taken to be equal to the maximum value observed during a gale. In the other this flow was zero: the condition after closing the last gap in the dike.

By combining the two sets of results an estimate for the raising of the highest level for the whole of the coast around the Waddenzee could be made. In March 1926 Lorentz endorsed the definite values, with his fiat.

There were several complications to be taken into account: curvature of flow lines and Coriolis forces due to the rotation of the earth came in for both calculations of tides and of surges. With regard to the latter the question arose whether the general raising of the sea should be considered and whether the problem of possibility of still

higher surges than the ones observed in the last few centuries should be discussed. It was realised that this did not belong to the task of the Committee which was restricted to the effect of enclosing the Zuiderzee. This point, more important than ever after the occurrence of the disastrous gale of February 1st, 1953, only just touched upon in the report of the Committee.

More than half of the report¹⁾ was written by Lorentz himself. Nobody realised in the beginning that it would keep him busy until far in 1926. He handed me his last contribution on September 13th, 1926, shortly before he left for the United States again.

In Ithaca, N.Y., he received the first copy of the volume of 345 pages which contains the result of so much ingenious work and also of so much toil.

The first thing of the report to be decided upon was its size. This was done during a meeting in July 1922, when the Committee was in an optimistic mood. Lorentz remarked that, once the size had been determined upon, the contents would surely follow.

A year later Lorentz wrote a letter to the Committee, expressing his thanks for a book presented to him on his seventieth birthday "to be read after the report has been completed". In September 1923 we had the first discussion on parts of the text at his home in Haarlem. This first conference was followed by many others, alternated or combined with discussions on the calculations. My notes mention sixty conferences in Haarlem, in three years time. It must have been a great burden to him, but for me those talks in his hospitable home, many of them with an interval

¹⁾ Verslag van de Staatscommissie inzake hooge waterstanden in verband met de afsluiting van de Zuiderzee. Den Haag, Algemeene Landsdrukkerij, 1926.

for lunch with Mrs. Lorentz, were a constant joy. Our relationship got more and more on a friendly basis, and in the end he mentioned other subjects besides that of the Zuiderzee. Evidently he was much concerned by the course which theoretical physics was taking in those years. The names of Heisenberg, Dirac and others were frequently used. Once he asked "Can you imagine me to be nothing but a matrix? It is hardly to be believed that all this is real".

But he could forget those cares and rejoice with other people. One New Year's evening he led children's games and he laughed more heartily than anyone else.

What have Lorentz' activities in hydraulic engineering led to ?

Directly they enabled us to make a prediction for the tides in the Waddenzee, a prediction which was magnificently confirmed by the observations during and after the construction of the enclosure dam.

It is difficult to check the predicted rise of the levels reached during storm surges. Every gale is different from its predecessors and it is hardly possible to make a comparison between a surge after the enclosure of the Zuiderzee and a similar surge before it. For a statistical treatment the data are rather scarce: only a dozen very high floods before and three or four after the enclosure. The general impression is that the calculated values are not far from the truth. There is one exception: at the ports of Terschelling and Vlieland, two of the Wadden Islands, the extremely high floods rise more than one foot higher than before, while the prediction amounted to six inches only. It seems that the maximum effect, which occurs along the enclosure dike, is also more than the predicted one of about four feet, but the difference is not great.

Before the enclosure of the Zuiderzee was accomplished, the sea walls of the islands of Wieringen and along the coast of Friesland have been raised according to the result of Lorentz' calculation (double coast line on the sketch). We may assume that they ensure the same degree of safety now as they did before.

This safety is not complete. Even higher floods than the historical ones are possible. Frequency curves for the chance of a surge of a certain height are being drawn in great numbers, especially after the 1953 flood. The first publication on this matter dates from 1939, fourteen years after Lorentz discussed the problem for the port of Harlingen.

The indirect consequences of Lorentz' work are more important still. I have mentioned already that it provided a working basis for the construction of the enclosure dike. Without the tidal calculations a jump in the dark would have been necessary on several occasions.

In fact, Lorentz put a whole section of engineering on a scientific foundation. After the Zuiderzee we know that even in very complicated cases it is possible to stick to a strictly theoretical method, that approximations, which are always necessary, should be justified and their consequences checked. Half a century ago many operations were jumps in the dark indeed. Nobody knew what would be the effect of shifting the mouth of a river to another place or deepening the entrance from the sea to a great port.

Now this is calculated in advance. The tidal inlets in the south-western part of the Netherlands will most probably be dammed off. It is already fairly well-known which tides, currents and flood levels will occur during the construction and after completion.

Lorentz made a great sacrifice, but it was worth while.

REMINISCENCES

(continued)

BY

G. L. DE HAAS-LORENTZ

LAST YEARS

When we look back upon the last years of my father's life we are filled with amazement, not only because of his unequalled youthful strength of mind, which enabled him at an advanced age to continue his leadership in all meetings where the prominent physicists of the world came together, but also because of his physical vigour, which allowed him to cope with this highly tiring kind of existence. What a blessing it was that my mother survived her husband, so that, while still in good health, she was able to accompany him on his travels and to take care of him faithfully until the end. It may be mentioned here, that after the death of my father my mother went to live at Amsterdam, where she died in 1931.

In July 1923 my father celebrated his 70th birthday. His retirement would begin with the opening of the new academic year. In connection with this fact he delivered his last lecture in the beginning of May of that year. Except for a few no one knew of this. Therefore this lecture was attended only by his regular audience. Einstein was one

of them, as was always the case whenever he was in Leyden. Afterwards he spoke about this last lecture as "von einem ergreifendem Abschied". However, it would soon appear that this farewell was not to be a farewell in the real sense of the word after all. On the initiative of a few physicists who were befriended with Lorentz, the Leyden University Foundation, through financial assistance rendered by some of my father's acquaintances, was enabled to invite him to give yearly lectures at Leyden and to offer him a fixed honorarium for his work. In this form the Monday morning lectures continued to exist. On the occasion of the golden anniversary of his doctorate (1925) this situation was given a permanent basis.

His seventieth birthday was celebrated quietly with a reception in the building of the "Teyler's Stichting". The French Minister presented Lorentz with the award of "Commandeur de la Légion d'Honneur". This day fell in the most busy period as to the calculations for the height of the enclosing dike of the Zuiderzee. In the previous article my father's appointment in 1918 as President of the State Committee has been mentioned. After having awaited for some time to see how far the engineers would need his assistance, Lorentz had taken upon himself in 1920 the entire leadership of the calculations.

As Professor Thijssse already related, the conferences and the work associated with the writing of a report began shortly after Lorentz' 70th birthday, and the committee hoped that everything would be finished by the end of 1925. During those years the work in connection with the Zuiderzee project took a great deal of Lorentz' time and energy. He had taken upon himself this exceptionally difficult work, actuated by a sense of duty towards his fatherland and a great love for his country, and has

brought it to a successful conclusion. However, he longed for the time when he would be able to resume his life of quiet study, as far as this would be possible in view of the duties which still were his as a member of the "Commission internationale de coopération intellectuelle", as well as in view of the scientific congresses and such lectures abroad from which in his opinion, he could not excuse himself. There were many of those in the years following 1925.

In anticipation of the timely completion of the *Zuiderzee* report my father had accepted an invitation to lecture in the United States in the autumn of the year 1925 and the following winter. This was the fourth invitation he received to visit America. Again he would have his headquarters in Pasadena. However, he postponed this trip for a year at the request of many of his friends when he learned how far the preparations had progressed made by an international and national committee for the celebration of the golden anniversary of his doctorate. And indeed, an impressive homage was paid to him on the December 11th, 1925, by many of his colleagues, admirers and friends, both in Holland and abroad.

First, in the name of the Leyden University, its Rector Magnificus conferred on Hendrik Antoon Lorentz the highest honour it was in his power to give, the Doctorate Honoris Causa in Medicine, in special recognition of what Lorentz had done towards the promotion of the education of the medical students. Professor Dr. J. van der Hoeve, Professor of Ophthalmology, functioned as promotor. (It should be mentioned here that on the occasion of the celebration of the 40th anniversary of Lorentz' professorship in 1918, the "Technische Hogeschool" in Delft had conferred upon my father the degree of Doctor Honoris

Causa in the Technical Sciences. Promotor on this occasion was Professor Dr. M. de Haas).

Then, in a crowded auditorium an homage of rare value and sincerity was paid to my father to which the true sympathy of all those present, the speeches and, last not least, the words of thanks from my father himself greatly contributed. His Royal Highness, Prince Hendrik, the President of the Council of Ministers, Dr. Colijn, and the Minister of Education Dr. Rutgers, were present at the ceremony. The senate was represented by almost all its members. An account of the speeches may be found in the issue of January 1926 of the periodical "Physica".

Three important facts should be mentioned here. Firstly, H.M. the Queen presented Lorentz with the Grand Cross of the Order of Orange-Nassau. Secondly, the participants in the celebration (the list contained 2000 names) had raised the money for a "Lorentz Foundation" for the promotion of the interests of theoretical physics. This made it possible to ask Lorentz to continue his Monday morning lectures in the same way in which he had done this before.

And thirdly, the Royal Academy of Sciences had decided unanimously to institute a "Golden Lorentz Medal", the design for which was to be made by Toon Dupuis. This medal would be presented at an interval of four years to the most deserving theoretical physicist. The first presentation has been made in 1927 to Max Planck by Lorentz himself.

The periodical Physica devoted the November-December number to the "fifty years old" doctor. This number contained an introduction by Balth. van der Pol and 25 articles dealing with scientific subjects by various authors.

At the end of the day of celebration a dinner was given

in honour of Lorentz, in which the guests from abroad participating were: Bohr, L. Brillouin, Madame Curie, De Donder, Eddington, Einstein, Henriot, Langevin, Lasareff, Lefebure, Jean Perrin, Verschaffelt and Wolfke.

From his delayed visit to America my father returned in the spring of 1927. Fortunately, there was no longer hard work awaiting him in connection with the Zuiderzee problem, for, as mentioned in the previous chapter, Lorentz had received the finished report of the Zuiderzee Committee while on his trip. How we all wished that from now on he would be permitted to enjoy those quiet years devoted to his own work for which he had longed for so many years.

Unfortunately, the autumn of 1927 proved to be a very busy and difficult time for a man who had entered his 75th year that summer. Shortly before the fifth Solvay Congress, devoted to modern quantum and wave mechanics, took place, a congress in commemoration of the centenary of the death of Volta was held in Como which dealt with the same subjects. My father was chairman of this congress also. During the congress in Brussels the centenary of the death of Fresnel was celebrated by the Académie Française in Paris. Lorentz adjourned the congress for one day in view of this fact and he went with the other members of the congress to Paris. On the night train my father prepared the address which he was to give on the next day on behalf of all members of the congress. From this address I quoted a few lines on page 32 in which my father related a precious memory of his younger years when he bought the works of Fresnel as the first contribution to his own library.

All those who were present at the Solvay Congress, again led by Lorentz, and who listened to his memorial

address full of piety in the large hall of the Sorbonne, yielded without doubt as always to "dem besonderen Zauber, der von Lorentz' Persönlichkeit ausgeht" quoting Einstein.

How could they foresee that all this would turn out to be the end of his activities, to be a "for the last time"?

THE END

On February 4th, 1928, Hendrik Antoon Lorentz passed away. Although the year 1927, the one in which he celebrated his 74th birthday, had been a busy and tiring one, he nevertheless began 1928 in good health and in his normal good spirits. Would still a few more years be granted to him after his return to Haarlem? No more work regarding the Zuiderzee problem was awaiting him there, while at the same time he had gradually retired from many activities. He himself hoped that this might be the case, as he told me shortly before his death, "to bring still some things to an ending", adding "but this is also good, I have behind me a wonderful and good life".

In fact, it was not to be! On Monday-evening, January 16th, after he had still given his customary lecture in Leyden and afterwards had lunched with our family as usual, my father was overtaken by a high fever brought on by erysipelas, which after an illness lasting a few weeks, caused his death.

Never before had there been such a general mourning in the Netherlands at the passing of a theoretical scientist, as there was at my father's death. I myself saw women from the lower classes in Leyden, as well as men from the upper classes, who were not able to control their emotions.

The municipality of Haarlem offered to take care of my father's funeral. Teyler's Foundation desired to have a

memorial service held in its building. My mother, knowing my father's wishes in such matters, did not wish to accept either offer, although fully appreciating these evidences of deep respect and great affection for the one who had passed on. On the day of the funeral, by instruction of the Postmaster General of the Netherlands, the telegraph service throughout the country was closed from twelve noon to 12.03. Thus the funeral of my father became almost a royal homage.

An abstract from the account printed in one of our prominent newspapers will give the readers an impression of the occasion.

"Today Haarlem has buried its great citizen Lorentz and has paid homage to this scholar in a manner both touching and dignified. Already in the early morning an unusual activity was noticeable in the city. Automobiles and carriages travelled back and forth, and it was significant that there was hardly an automobile to be had for those desiring one. From many buildings, such as the Town Hall, the Main Church, the Railway Station and the Cavalry Barracks flags were flown half-mast. In the main streets lanterns draped with crape were burning. Long before the appointed hour thousands and again thousands of people had gathered along the road, while there was great activity about and at the cemetery. The police force had taken the necessary precautions so that disturbances would be avoided.

At about half past eleven a special train from Leyden arrived which carried a large number of students and interested people from that town. While the bells of the cathedral were tolling, the body was carried from the house in Julianastraat to the hearse. Although a request had been made to omit flowers, an extra carriage was

needed to carry the wreaths which had arrived from various parts of the Netherlands and from abroad. The hearse was followed by 15 mourning coaches. The representative of the Queen was seated in the first one, the aide-de-camp of His Royal Highness Prince Hendrik in the second. Members of the family occupied the next five coaches, whereas the others were reserved for the guests. At the moment that the procession started, the bells of a number of churches, Protestant as well as Roman Catholic, spread their mournful notes of the city. The thousands of people along the road took off their hats in token of deep respect when the procession passed. Moving through the Groot Houtstraat it continued to the Groot Markt, where it stopped in front of the Town Hall. Here the Aldermen and the acting Mayor were waiting, and placed a large wreath on the bier, on behalf of the municipality of Haarlem. The Mayor himself was one of the guests and rode in the procession. The procession then went on through the Market Place, along Smedestraat, Kruisstraat, Kruisweg, Kennemerplein and Schoterweg to the Kleverlaan.

On arrival at the cemetery the simple coffin, covered with a few flowers, was placed on a bier and between two rows of scientific and government organisations was carried to the grave. During a moment of solemn silence the coffin was lowered. At the request of the family only a few guests spoke.

The first speaker was Professor P. Ehrenfest, representing the Netherlands, then Lord Rutherford for England and Professor Dr. P. Langevin for France, Professor Dr. A. Einstein for Germany. At the conclusion the son of the deceased, R. Lorentz, spoke a word of thanks”.

At the University of Leyden, all festivities in connection



The funeral procession crossing the Grote Markt, Haarlem (in the background the townhall), February 9th 1928

with February 8th, the Dies Natalis of the University, had been cancelled except the Rector's oration. On the day after the funeral, on Friday, February 10th, a solemn memorial service for Lorentz was held in the Great Auditorium. The commemoration oration was given by Professor Einstein.

We shall end this chapter with the touching words spoken by Professor P. Ehrenfest at my father's grave.

FUNERAL ORATION

BY

P. EHRENFEST

Hendrik Antoon Lorentz dead! Since death was powerful enough to close the eyes of Lorentz, the ancient question arises in our heart: "what after all may be the meaning of our human lives?" And we ponder about the life of Lorentz, and our heart is deeply moved. Then, through all our doubt, a warming feeling of security grows. To our surprise.

We dare not speak of this at first, not acknowledge it, either to ourselves or to our closest friends. When we face this grave the feeling of security is still there. From where does it come?

An honourable place among men was granted Lorentz, praise was accorded him, unstintedly by his own nation and by the world at large. Now, when he has left us, tributes still reach him, and his memory is honoured in the land of his birth and beyond its frontiers. And with honest appreciation goes that which exceeds it in worth, honest affection. Let us search deeply to discover why this life should become a source of security to our own lives.

Lorentz the explorer, the master who reveals what he found to the minds of others! Of great beauty is that which

it was granted him to discover in his work and to fit into a theory; in physics, which has his great love.

He continues the work of the great masters. His great creations are bridges that span the wide gaps between physical theories of the nineteenth century, which now could obtain their final form.

His keen critical mind, always guided by honesty and directed towards absolute objectivity, draws a clear line of distinction between that which is completely established in human reason and that which is still incomplete and he fastens the attention with great emphasis upon the many still baffling problems.

Thus his work becomes at the same time a firm foundation and a constantly flowing fountain for the brilliant research workers of the younger generation, who love and honour him as one of their great masters. And with how great a devotion, how lively an interest he just follows their work and watches the personal growth of the most gifted among them, not only in the Netherlands, but all over the world.

Read Lorentz' writings, read his text books. A picture of a workshop arises before our eyes, a workshop with high windows filled with light, the heartwarming light of the morning sun. And behold the Master at work, with how great a devotion he uses his instruments. By preference he uses the simplest of tools, most fit for the purpose. But fine instruments of precision are ready at hand as well, conveniently arranged, ready to be used. And all glitter from the constant daily use through years and years.

And because the Master shows us with so great an affection which instruments came to him from Christiaan Huygens, and which from Fresnel or Maxwell, and which

from other masters, we may well guess that many others of these fine ingenious tools had been invented and made by himself.

But that the Master does not tell us. The Master in his workshop filled with sunlight. The Master with his dark eyes and his eloquent smile.

And we enter deeper into the contemplation of the figure of this man. Into the contemplation of this so perfectly ripened harmony.

In each one of the expressions of his life his whole personality is revealed to us, as through a miracle, in its full width and depth. And we cannot divide that personality into sundry parts, separating one line in this picture from the other. Neither would we do it if we could.

The irony of his eloquent smile, the irony through which he stills our soul. Where in his smile is this irony divided from the quiet depth of the emotion, with which he seeks to enoble our joy?

And when Lorentz with great kindness uses an old, perhaps antiquated form of expression, we discover suddenly, to our shame, that by doing so he has reverently greeted a simple warm heart for which this old form of utterance retains a living content: the heart of a young mother, the heart of a widow in her loneliness.

In his work, in his life, we may not separate his affection from the faithfulness with which he carries out his obligations. Remember the years of labour which he devoted to the solution of the problems connected with the *Zuiderzee* or to the publication of the works of Huygens. Truly Lorentz is faithful.

Our conscience is touched by his faithfulness.

That we must do the best we can, in all honesty, according to the measure of our capacity.

Endeavouring after clarity in our research, after clarity and honesty in our teaching. For only thus shall we reverently remain aware that nature is beyond all human comprehension.

And that all our actions should be a devoted surrender, a loving service to mankind and with this a struggle against the temptation to serve ourselves.

To do the best we can, with joy.

Truly Lorentz is faithful.

He enjoys the magnificent beauty of California and of the Alps. But he feels at home in the woods and on the heath of the Veluwe, and in the dunes. He feels at home too when he passes the canals of Leyden, when he enters the buildings of the University, when he is in his small lecture room in the physical laboratory.

And thus it is with the beloved familiar sounds of his native language.

Thus it goes with Lorentz the world citizen.

Thus it goes with Lorentz everywhere, with this man of the receptive mind. Always we find him faithful and true to himself.

Thence his deep respect for the personality of his fellow-man, for freedom of any sincerely formed conviction.

Only when he is confronted with lust of power, dominance and compulsion, slyness, we see him suddenly lose his composure.

And only difficultly regain it.

Regain it for the tenacious battle against these worst enemies of man and of human worth.

And always does he carry on this fight with the inner weapons of the spirit; he distrusts all that leads to outward conflict, distrusts it from the very depth of his soul.

And thus, at home, he leads us along the paths of

tolerance, as he does it abroad, when it is a matter of peace among nations.

And thus in his utter fidelity to his own best self and to others, he remains the helper in need, the consoler in moments of bitter anguish — to the very last.

He whose ever youthful heart is with the work of the young to the last;

He whose warm devotion guides the developing minds of the young to the last;

He, when at last death comes to claim his fruitful life, meets the end with the tranquillity of wisdom.

We bow to the memory of the ancestors of Lorentz. We bow in reverence before the grief of those who were tied to him with the closest of ties.

And with affection we remember Lorentz' grandchildren. The joy that he felt in having them has enriched greatly the evening of his life. Better than we, will they once be able to understand the life of Lorentz, and it will be a blessing to them.

'Es ist mir ein Bedürfnis nur noch einige Worte zu denen zu sagen, die Woche für Woche auf dem "Maandag College" sich um Lorentz versammelten. Die einen seit kurzem, andere seit Jahren, mancher seit Jahrzehnten.

Auf dem Hintergrund der schwarzen Tafel mit den Formeln in Lorentz's klarer Schrift sehen wir seine zarte, uns so teure Gestalt; vorüber gebeugt — die Finger mit der Kreide spielend — in der freudigen Spannung uns zugleich die Schönheit und die Schwierigkeiten irgend eines neu in der Wissenschaft sich entwickelnden Gedankens sehen zu lassen.

Und plötzlich besorgt, "dass er uns wieder zu lange aufgehalten hat" schliesst er mit einer letzten Andeutung die er "hofft in der folgenden Woche näher zu erläutern".

Lächelnd verabschiedet er sich von uns; dem und jenem eine persönliche Frage stellend oder auf eine Frage antwortend. Wir scheuen uns ihn noch länger aufzuhalten. So verschieben wir manche Frage an ihn auf "den folgenden Montag" und schauen ihm nach, wie er — noch im Gespräch — über die kleine Treppe das Vorlesungszimmer verlässt. —

In jedem kleinen Zug von Lorentz, in jeder seiner Lebensäusserungen offenbart sich uns — wie durch ein Wunder — seine ganze Persönlichkeit.

Durch die ganze Persönlichkeit dieses Mannes aber spricht etwas Grösseres, Umfassenderes zu uns'.



REMINISCENCES (conclusion)

BY

G. L. DE HAAS-LORENTZ

Shortly after my father's death a national committee as well as a few local committees were formed in order to find ways and means to preserve in a dignified manner the memory of H. A. Lorentz. Thanks to their initiative three Lorentz monuments could be erected. Thus the magnificent Lorentz statue arose on the picturesque slope of the Sonsbeek estate in Arnhem. The sculptor was L. O. Wenckebach. On September 10th, 1931, the solemn unveiling of this statue took place by H.R.H. Princess Juliana. At the right of the central figure, the figures of three great predecessors, Christiaan Huygens, Augustin Fresnel, James Clerk Maxwell, are found in bas-relief; on the left are found Lorentz' great contemporaries: Max Planck, Albert Einstein and Niels Bohr.

The entrance to the department of theoretical physics of the physical laboratory at Leyden was replaced by a small gateway, designed by the architect C. Royaards. Above this a small monument, in haut-relief, was constructed, made by the sculptress Mrs. C. Franzen-Heslenfeld. It was unveiled on November 3rd, 1933, after an address had been delivered by Professor J. Huizinga.

The best resemblance of Lorentz is shown in the bust made by the sculptor Professor A. W. M. Odé. It is to be found on the Lorentzplein in Haarlem, where it was unveiled by H.R.H. Prince Hendrik on November 3rd, 1929.

Soon after the funeral the City Council of Haarlem decided to re-name part of the Julianastraat, where my father had lived during his last years, and to call it Lorentzplein. Since then, in the course of the years, many streets, lanes, squares and quays in the Netherlands have been named after my father, along with schools and lycea, so that the name Lorentz can be found in almost every town.

In the gables of the houses in which my father had lived for a great part of his life, a small memorial tablet was placed. This were the houses: 48 Hooigracht in Leyden, and 49 Lorentzplein in Haarlem. In the gable of the house at 38 Steenstraat, Arnhem, where my father had lived during his entire stay in that city, a memorial tablet had already been placed before 1920. The house was demolished during the battle of Arnhem, on January 28th, 1945. The tablet was removed together with the debris. No tablet can be found in the gable of the newly erected house.

A beautiful edition of the collected works by H. A. Lorentz in nine volumes appeared with the publishers M. Nijhoff in the Hague, between 1934 and 1939, edited by P. Zeeman, P. Ehrenfest and A. D. Fokker. The first volume contains the thesis both in Dutch and in French. In the other volumes are found all the scientific articles in sofar as they had not already been published in book form. They are printed in French, German and English. In the last volume one finds several speeches and commemoration orations.

This year marks the one hundredth anniversary of the birth of Hendrik Antoon Lorentz. Neither his name nor his personality have been forgotten. The three cities where he has lived commemorated solemnly this occasion.

In Arnhem a commemoration service took place on January 31st, attended by many friends from all over the country. This date had been chosen because it came close to the date of Lorentz' death on February 4th. The ceremony was introduced by the placing of wreathes at the base of the statue in Sonsbeek. Afterwards, Ch. G. Matser, Mayor of Arnhem, spoke in the large hall of Musis Sacrum. He was followed by Professor Dr. A. D. Fokker, who spoke about the personality of Professor Lorentz against the background of the past. He in turn was followed by Dr. J. E. Baron de Vos van Steenwijk, President Curator of the University of Leyden and President of the "Hollandsche Maatschappij van Wetenschappen" at Haarlem. After him spoke Professor Dr. A. J. Kluyver, Head of the Department of Physics of the "Koninklijke Nederlandse Akademie van Wetenschappen". Professor Dr. J. L. Duyvendak, Rector Magnificus of Leyden University, Mr. O. P. F. M. Cremers, Mayor of Haarlem, Professor Dr. H. B. G. Casimir, who spoke on "the influence of Lorentz' ideas on modern physics". These orations were collected as reprints from the periodical "De Gids" of March 1953 and published in one volume under the title "In memory of H. A. Lorentz".

The Mayor of Arnhem announced in his speech that the City Council was planning a Lorentz Scholarship for the purpose of helping impecunious young people from Arnhem in their study in science at one of the Dutch Universities.

That evening a fearful storm broke out, which would become the cause of the disastrous inundations of February 1953. The enclosing dike of the Zuiderzee resisted — an impressive coincidence; this great tribute to Lorentz' last work and this memorial day.

In June the University of Leyden commemorated the centenaries of H. A. Lorentz and H. Kamerlingh Onnes on the same day. Their birthdays had been respectively July 18th and September 21st.

The Netherlands government instituted a Lorentz Chair, which would be occupied each year for several months by a guest-professor in physics. A former pupil of Ehrenfest, Professor Dr. G. E. Uhlenbeck of Ann Arbor (Michigan) was the first in 1954.

The solemn commemoration took place in the large auditorium, where the professors J. Clay, W. J. de Haas and J. H. Thijssse spoke. During the same week a private congress was held at which Dutch and foreign physicists participated. The subjects under consideration were mainly connected with the work of Lorentz and Kamerlingh Onnes. Professor Dr. C. J. Gorter, who succeeded W. J. de Haas in 1948, was chairman of the congress.

In memory of Lorentz as well as of Kamerlingh Onnes an exhibition had been arranged in the "Rijksmuseum voor de Geschiedenis der Natuurwetenschappen", of matters dealing with the history of science. Manuscripts, pictures, objects of various description and instruments had been brought together. Although the committee in charge of the Zuiderzee works was overloaded with work by reason of the inundation of the province of Zeeland, it had sent a very accurate model, with accompanying explanatory text, of the Zuiderzee reclamations.

In Haarlem, in the month of July, the "Hollandsche Maatschappij van Wetenschappen" and the Teyler's Stichting organised a simple memorial service in the building of the latter, testifying to the gratitude and devotion they felt towards Lorentz.

The concluding pages contain the commemoration speech by Professor Dr. H. B. G. Casimir held in Arnhem on January 31st, 1953.

THE INFLUENCE OF LORENTZ' IDEAS ON MODERN PHYSICS

BY

H. B. G. CASIMIR

"Each branch of natural science presents the same picture of related investigations and interwoven ideas". I am quoting these words from an address delivered by Lorentz at the "Koninklijke Akademie van Wetenschappen" at Amsterdam in the year 1915. Nor would it be in accordance with his wishes were I to suggest that present-day physics is merely supplementary to what he, Lorentz, has accomplished. To reduce the entire development of a branch of science to the work of one person, however brilliant, would present a wrong picture scarcely in accordance with the unselfish impartiality so characteristic of Lorentz, nor with his ideal of peaceful co-operation of scientists, so close to his heart. It is not in this sense, therefore, that I desire to speak about the continuing influence of Lorentz' ideas.

The development of science has taken place with increasing speed during the last half of the century. In many ways the situation was, and still is, obscure. It is not merely a question of a flood of new facts presenting themselves, or of new mathematical methods being employed, but new ways of thinking in absolute contrast with earlier

views are being introduced. Caught in a flood of new events, bewitched by a surprising, unexpected and intense desire to keep up to date, at least so far as one's own limited section of the total field of science is concerned, the present-day physicist easily loses sight of the great lines. The swimmer who hardly can keep his head above water has little time to think about the source of the current from which the small whirlpool issues in which he struggles, and of which it is only a small part. Thus the danger arises that the world will have but a formal, book-like admiration for the great figures of the past, even of the recent past. One may liken it to the respect which a schoolboy displays for some statesman of whose noble character he has read in his books, without however having given thought for a moment to the way in which this nobility was shown.

But as soon as one tries to draw away from the confusing details, one discovers that we are concerned with an evolution, speedy perhaps, but yet gradual, rather than with a form of revolution. When one does this, the importance of the work of Lorentz begins to stand out as of its own accord, and it becomes clear how sound theories retain their worth. Lorentz himself has expressed this most strikingly: "Henri Poincaré a une fois dit que les théories sont passagères comme les vagues de la mer, se suivant comme elles les unes les autres. La comparaison n'est pas tout-à-fait juste, parce que les vagues ne laissent aucune trace, tandis qu'il reste beaucoup des bonnes théories".

Two tendencies have merged with regard to present theories. On the one hand one finds the phenomenological theories, the tentative, prudent theories, as Lorentz was in the habit of calling them. They are based, as much as possible, on the directly observable. They reached prin-

cipally their final state at the beginning of this century. To this Lorentz has contributed his share. I said "principally their final state". That does not mean that nothing new or surprising might be found any more, but that, to use a big word, epistemologically nothing new can be expected. The further development is either purely mathematical, or else it finds its application in the fields of technics and possibly astronomy or biology. Maxwell's equations comprise the entire field of electrodynamics and of theoretical electrotechnics. One example may serve: the theory of the electric fields in wave tubes etc., at present used in radar, would have had no secrets for Lorentz. How wonderful an insight Lorentz had into the phenomenological theories, — how masterfully could he play all of them! Thus, at an advanced age, he made his calculations on the tides in the Zuiderzee, solving in this way a in all respects technical problem. An illustration of the development of the physical theories here under consideration.

On the other hand there are the atomic theories. In a certain sense these are of much older origin, but qualitative and speculative, until in the second half of the 19th century the mathematical and quantitative methods of the phenomenological theories were used to describe the behaviour of atoms and molecules. And a rich harvest resulted: The kinetic theory of gases, developing later on into statistical mechanics, makes it possible to treat the thermic qualities of matter from a purely mechanical point of view. Lorentz has worked on nearly all aspects of theoretic physical atomistics. His greatest contribution is the application of the theory of electricity to atomic electrical particles, which led to an explanation of the electric, magnetic and optical properties of matter. Together with this a comple-

tion of the phenomenological theory is reached, issuing in the theory of Einstein.

A rich harvest, a perhaps unexpected measure of success. The atoms, so speculative in the beginning, gained greater and greater reality. If at first they were but symbols used for arranging the wealth of phenomena, — just in Lorentz' earlier writings the idea that we are working with symbols, turns up several times —, their reality gradually becomes more and more accentuated. The electron appears to be a definite particle with a charge and mass exactly alike for all of them. The ether too first appeared as a symbol, but this symbol slowly faded until in Einstein's theory it was thrown to the winds.

How brilliant Einstein's conception may have been, the quantitative treatment and the accompanying concretisation of the atomic concept proved to be a greater and as to its consequences more important occurrence. As to its relation to the ether theory: Lorentz himself, also in later years, liked to use the symbol of the ether. However, in the first chapter of his "Theory of Electrons" the theory of electric fields is presented with crystalline clear mathematical simplicity, without any unnecessary accessories. And this very treatment makes it possible to explain clearly the properties of a body as due to the play of the electrons. Still this is the way to deal with the interaction between matter and radiation.

Quantitative treatment of similar atomic particles possessing accurately known properties, this is perhaps the most essential characteristic of modern physics. But though admitting the successes, there was also a limitation. While in the beginning doubt existed as to the reality of the atoms, but at the same time a most complete confidence in classical mechanics and the deterministic

description of space and time that goes with it, the result proved to be different. The arguments for the existence of atoms and electrons became more and more compelling, but ever more threatening at the same time, what Kelvin called, the dark clouds which gathered on the horizon. It became more and more obvious that the classical methods and notions were not sufficient. And thus a change in the aspect of physics took place. Instead of the exact treatment of a model to which none too high a degree of reality could be assigned, came the tentative and incomplete description of particles and systems, the reality of which could not be called in question. The quantum theory of Max Planck, the even more advanced ideas of Einstein, the theory of Bohr based on both, and finally the quantum mechanics of Schrödinger, Heisenberg and Dirac, are steps leading towards a more or less complete formalism, which may take the place of classical mechanics and electrodynamics. Lorentz did not contribute to this development to the same extent as to which he influenced the first stadia. But within the framework of classical reasoning he advanced the theory as far as possible and thus created a fresh starting point from which all further theories depart. Is there a contrast between Lorentz the classical scholar and the moderns such as Bohr and his contemporaries? Perhaps to a certain extent this may be admitted. To Lorentz the reality of the atoms and the electrons turned up as a beautiful result, to Bohr this reality had become a nearly self-evident fact. But, if this starting point is accepted, the atom, always returning to the same condition, would show a sign of stability unknown to continuous classical mechanics. Then one will no longer regard the failure of classical mechanics as a threatening cloud but as a self-evident fact which one should take into con-

sideration from the very beginning.

The road to a new mechanics has been a long and difficult one. There may be a difference of opinion as to whether one can apply the term definite to the result reached as yet; especially as far as its interpretation is concerned. It is certain that the result could only be reached by continually using as close an analogy as possible with the classical methods, which remain valid as limiting cases.

One of the problems with which Lorentz too struggled has not been solved yet. In Lorentz' field theory the structure of the electron remained an enigma. Was it a point? No, for then the field energy would be infinite. Was it a charged sphere? If so, how would the particle stay together, while the theory of relativity, the validity of which one surely would want to keep intact, creates additional difficulties. The same difficulties remain principally unsolved in the modern quantum mechanical formulation of the field theory. Their partial solution has led to some wonderful experimental results, but also to a difficult, impenetrable forest of mathematical symbolism.

I will stop at this point. I fear that the addition of more details would not make this outline clearer. Moreover, one should be able to express one's admiration in a few words and to give one's view regarding the development of physics in a somewhat apodictic fashion. The field of physics itself cannot be dealt with in so short a time.

But before I finish I have a confession to make. When I was preparing this speech I used among other books the ninth volume of Lorentz' collected works, which contains lectures intended for larger audiences. I hoped to find there a key to Lorentz' ideas with respect to the essential meaning and the procedure of physics, and also about the rela-

tionship between his work and his general outlook on life; in this I was not disappointed. But I also expected that his ideas would be typical of days gone by and no longer suited to the present way of thinking. I imagined that, notwithstanding Lorentz' honesty and high-mindedness there would be a lack of understanding for tentative struggle, for an impulsive, somewhat artistic, way of working. But in this I made a mistake. It is everywhere apparent that Lorentz, though he liked to use concrete illustrations, was well aware of their relative value. In his professorial address he says: "Thus in using too many illustrations, one may miss the main point"; and somewhat further "The word 'forces' is but a name for certain entities present in our formulae". This mode of expression might occur in any textbook on modern quantum mechanics. At all times he gives evidence of disliking dogmatism, points out that the problems of physics may be dealt with in many different ways. And on the level of general human feelings, how great an understanding and measure of appreciation is apparent in his commemoration oration devoted to Boltzmann.

If you think that my previously incorrect expectation about Lorentz' ideas is due to a measure of arrogance, I may best excuse myself by referring to the fact that Lorentz accused himself of making the same mistake during an intermission of the Solvay Congress. We find it in a part of his speech in commemoration of Fresnel, the words of which might be applied almost literally to Lorentz himself. "Aussi n'ai je pu m'empêcher, ce matin, de dire à Madame Curie: Fresnel n'y aurait rien compris. Ce fut irréfléchi et je dois me corriger. Certes, si Fresnel avait pu assister à nos discussions, elles l'auraient tout d'abord effrayé, et il se serait peut-être dit: 'Est-ce bien

cela qu'est devenue ma physique?' Mais bientôt il serait entré dans nos idées, il aurait su en dégager ce qui est essentiel et fondamental, et je suis sûr que, avec son génie et son don de pénétration, il aurait été pour nous un maître et un guide".

In their introduction to the Collected works of Lorentz, Fokker and Zeeman quote the same passage. I know of no words which could express better that which I have tried to say in so imperfect a manner.