

Johannes (Jan) M. Burgers was born in Arnhem in The Netherlands on January 13, 1895. His potential as an outstanding scholar was recognized early and he started to work as a Professor of "Aerodynamics, Hydrodynamics and their applications" in the Department of Mechanical Engineering, Shipbuilding Engineering, and Electrical Engineering of the Technical University in Delft in 1918, two months before he received his Ph.D. in Physical and Mathematical Sciences from the University of Leiden under the supervision of Paul Ehrenfest. After an impressive career in fluid mechanics in The Netherlands, Jan Burgers moved in 1955 to the University of Maryland in College Park. MD, where, first as a Research Professor and subsequently as a Research Professor Emeritus, he remained professionally active till his death on June 7, 1981. A considerable amount of information about Jan Burgers and his work can be found in the well-known volume edited by F.T.M. Nieuwstadt and J.A. Steketee [1]. This volume also contains biographical information.

When we went through the Archives at the University of Maryland and at the Delft University of Technology we found 35 typewritten pages of biographical notes written by J.M. Burgers himself in 1962. These autobiographical notes cover two topics: a first chapter about his environment at home and a second chapter dealing with school and university education. In the manner that these autobiographical notes were written, it would seem that they were intended to be followed by additional chapters. However, checking the archives at the University of Maryland, at the Delft University of Technology, and at the Niels Bohr Library of the American Institute of Physics we have been unable to find any additional chapters. Hence, we have concluded that Burgers did not continue to compose a more complete autobiography. We did find a list of names of persons to whom these autobiographical notes were sent in 1962. The only other autobiographical information we are aware of are some memories of his early work in fluid mechanics at the Technical University in Delft that have appeared in the Annual Reviews of Fluid Mechanics in 1975 [2].

Because of their great historical interest we are using the occasion of the 15th anniversary of the J.M. Burgers Centre to make the autobiographical notes of Burgers available to the scientific community. The first chapter discusses extensively the influence of the parents on the young Jan Burgers. The second chapter deals with his primary and secondary school education and with his experience as a student and young scholar at the University of Leiden including the somewhat complex interactions with his Ph.D. supervisor, Paul Ehrenfest. We are publishing these autobiographical notes verbatim except for some obvious spelling and grammar corrections.

Acknowledgment

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References

1. F.T.M. Nieuwstadt and J.A. Steketee, eds., Selected Papers of J.M. Burgers (Kluwer, Dordrecht, 1995).
2. J.M. Burgers, *Ann. Revs. Fluid Mech.* 7 (1975), pp. 1-11.

I have lived with my parents from birth until my 19th year, when I left for the University of Leiden. Since the education which I have received at home, has had a decisive influence on my development, I would describe some features of the environment which has acted upon my brother and me. To expand this into an actual biography of my parents, with observations on the circle of relatives and friend amidst whom they lived, would require an amount of work much larger than I can afford at this moment, although it would form an interesting story. Moreover, to my regret, there is no record of many valuable details, and often my memory gives only vague indications.

My father was born October 23, 1862, in Arnhem, from relatively humble parents. My grandfather, whom I have not known, was a carpenter. He seems to have had a good sense of humor and the gift of acting, both matters which my father inherited from him (and my brother afterwards). Father had no more than a somewhat scanty primary school education; later he learned some french and german, and he certainly developed a good style for official letter writing, concise and to the point. From 1876 till 1886 father worked in the Arnhem office of a firm for the despatch of parcels and goods, where an uncle of his was local director. For some years he lived with his mother in the village of Oosterbeek near Arnhem (walking to and from every day, a distance of about 4 km), and from 1884 to 1886 he also fulfilled the evening service at the post office in Oosterbeek, at the same time acting as telegraph operator. In 1886 he became assistant at the railway post office in Arnhem, where the parcel post from Germany is received and subjected to customs inspection. His work was heavy : from 8-12 and from 1-5 in the daytime, plus every other evening from 8-10.30, and every other Sunday morning and Sunday evening, There has even been a period of about 1.5 years, when he had to work every Sunday morning, and evening. Free Saturday afternoons were utterly unknown at that time. Often there was work in (unpaid) overtime, when trains were late.

Father has developed himself extensively by reading. I do not know when this self-education has begun. It seems that in 1888 a friend once sold to him a small induction apparatus (operated with a galvanic pile, such as was used in the old days to produce nice electric shocks), and added to it some volumes of the "Ideen" by the author E. Douwes Dekker (1820-1887), who wrote under the pseudonym "Multatuli". Multatuli, in deeply felt, earnest and at the same time brilliant statements of his ideas, attacked many conventions which stifled society, and penetrated into everything, with an outlook far surpassing that of almost everybody at that time in our country. These books have opened the eyes of many men and women in the Netherlands ; they also did this to father and stirred him profoundly. They must have awakened into activity an already existing urge to understand. Father's genuine enthusiasm grew to such extent that he began to collect more books and also to make instruments for himself, or to buy some parts; he wanted to see what he had read with his own eyes and with his own apparatus.



In this he found sympathy and support from some friends, while also, from their marriage (September 8, 1893), my mother has fully supported all my father's inclinations for study.

I do not know whether she came first in this respect, or whether these friends had come earlier, but my mother's marriage present to my father was a good microscope.

Although not being a scientist in the strict sense, my father had an excellent way of explaining to other people that what he had understood himself. He was very versatile in performing demonstration experiments with his instruments, and he started to give series of popular lectures on various subjects, a course in electricity being foremost.

Again I regret not to have data about the way how it began.

Apparently father originally had been reading sections from Multatuli's works to members of a society of freethinkers "De Dageraad" (the Dawn); he had a good voice for reading aloud and for speaking in public; he always took his hearers in. I think that this was connected with his sense for acting, and also with a sense of fairness and of balanced criticism (he never became a hero worshipper).

I cannot reconstruct how father's lectures started as a more or less regular feature in the family life. They were of various kind, sometimes public lectures upon the invitation from an educational society, or a school, or from just a group of interested people relatives, friends or other acquaintances, people from intellectual circles, or some old ladies of the aristocracy who took an interest in science. Lectures were also given in neighboring cities, requiring a lot of preparation for the transportation of the instruments. From about 1908-1938 each winter in Arnhem father gave about half of the series of "Popular Lectures" arranged by the local Physical Society, lecturing on 7 or 8 consecutive Sundays from 7 - 8 p.m., before an audience of simple people, who were very devoted to father and felt the spell of his words and his experiments.

The main subjects of father studies and lectures were elementary electricity, static and galvanic as it was then called; the microscope as an instrument, with its history; the microscopic living world; astronomy; geology.

Every lecture was carefully prepared beforehand. For many lectures father also made extensive collections of slides (mainly reproductions from illustrations in books or periodicals; also from microphotographs which he had started to make, and photographs from specimens of his collections). This was done in the spare hours and the free Sundays which were left to him by his work at the post office, and my father often has said that doing this, notwithstanding the heavy work at the office, was the one thing which has kept his mind open and has protected him from becoming depressed.

It is true that the subjects mentioned looked more simple in those times than they do now. But it should also be kept in mind that many qualitative demonstration experiments can be extremely interesting to all kinds of people, if well explained. We enjoyed very much the whole "physique amusante", which developed from experiments on static electricity. Father first had one Topler-Voss electrical machine (acting on the induction principle), with glass disks, for producing sparks.

This machine was transported in a wooden box to every place where lectures were given. It was operated by hand - how often was it my task to turn the handle for the demonstrations. Later on a second one was acquired, and then two Wimshurst machines which were more powerful.

One of these had 4 glass disks, and could be operated only during frosty winter days, when the room was heated and the air was dry. It gave sparks of 19 cm length, which we sent through large pieces of quartz or through crystals, in order to see the reflections illuminating the whole piece.

With this machine we also could work an X-ray tube which father had got from a doctor, as it had become too hard for operation by the then existing induction coils (at that time we had no idea of the danger which may arise from radiation).

We had numerous Leyden jars, and also so-called "Franklin plates", capacitors made from a piece of sheet glass, with tin foil on both sides. Often one side was cut up into numerous little pieces, so that one could see the small sparks between them during the period of charging, and then a very bright spark, beautifully ramified, at the moment of discharge.

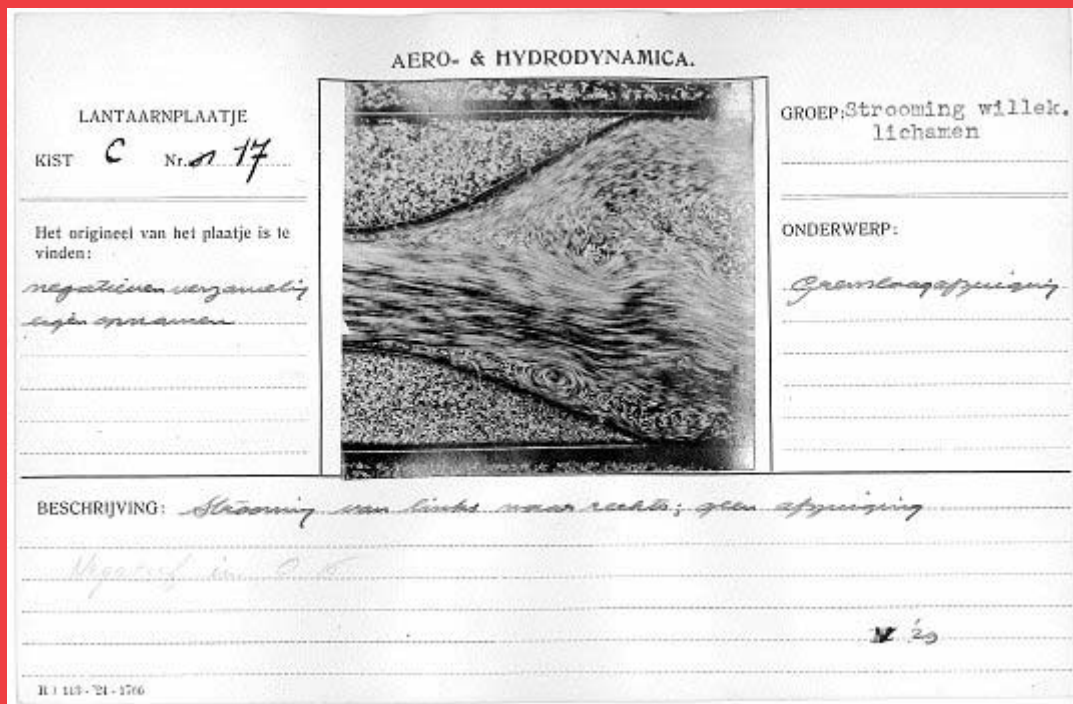
There were also many Geissler tubes, for the discharge through rarefied air, with colored glass bent in various shapes. We had galvanic batteries (father mostly used those which have a mixture of diluted sulfuric acid with potassium bichromate as electrolyte). Father made himself galvanometers with so-called "a-static" needle systems, which were suspended from a thread of unspun silk, obtained from silk worms which mother reared during one summer. Electroscopes were a specialty as well. The point of glory of the course was a demonstration of wireless telegraphy, with the Branly coherer as detector.

As far as I can remember, there have been many books at home though often bought second hand. There was also a collection of minerals and later on there were shells, mother sometimes found an odd collection on the market place, left over from a sale of furnitures. My father even gradually brought together a collection of historical microscopes, again mother often was a great help in acquiring valuable items; after his death this collection has been presented by my brother and me to the Government Museum for the History of Science in Leiden.

As I mentioned, my father's interests in these subjects were supported not only by my mother, but also through the presence in Arnhem of several friends with similar interests. They often worked together. Also father's acquaintance with a very good instrumentmaker helped him greatly during many years. I still have the remembrance of the building of a large Ruhmkorff inductor, on which one of father's friends (still

alive at this moment, (February 1962, aged over 80 years) cooperated for many months but it did not develop the power father had hoped it would give.

Usually there were many discussions between father and his friends, on a wide variety of subjects. Since these friends at the same time were good friends to my brother and me, they have performed a significant part in our education. For instance, they helped us with our playthings, with work in cardboard, wood, or other forms of handicraft with drawing and sketching; and further with intelligent information and advice on many subjects.



A so-called "Lantaarnplaatje" a former slide of the current dia-projector

Nearly always there was a microscope on my father's table. From our youth we heard about the strange world of life which is found in water. Once we had an aquarium and saw, the making of a floating nest by the spinning water beetle, and the metamorphosis of a dragonfly. Father had various books on natural history, and amongst them there was Ernst Haeckel's "Kunstformen der Natur", with 100 large plates of beautiful representations of animals and plants, in particular the microscopic ones : Radiolaria, Foraminifera, Diatoms; various types of jellyfish and polyps; and many others.

During the summer we made many walks with father and mother in the surroundings of Arnhem, which have always been very beautiful, and which at that time were still much more free and unspoilt than they are now. We looked, for interesting stones, and often found pebbles with fossils.

Father's mind was directed to clearness in thinking. At the same time it was, what I would call, "integrating", seeing things together and trying to understand their relations. Although attentive to details and to their meaning, his mind was not analytic in the sense that he felt interested in precise distinctions and divisions for their own sake. His interest moved easily from the wonders of the microscopic living world to the stars and their immense distances, or to demonstration experiments in electrostatics or galvanic electricity. At the same time he was a good talker, who liked a joke and who could take jokes, and he was a good actor. He could entertain, with often sparkling conversation, our many relatives and acquaintances, who came to our home for friendship and conviviality.

My father implanted in me reverence for the wonders of nature. I have inherited his desire to see things together, as well as his broadness of interest (I went even further than he did). I have always been an absorber of knowledge and one who likes to reproduce thoughts in a re-arranged form trying to bring out some general point of view, more than one who continually probes for new relations and tries to make discoveries. I have gone more "into the breadth" than "into the depth". But I can witness of the joy which results from understanding and from a wide area of interests. What knowledge I have, has always been for me something to live with - it is a part of myself.

On the whole, father's inclination was "descriptive". I may also characterize it as "constructive" or "educative", as opposed to breaking down a lot of ideas by continual criticism. His was a mind sustained by reverence for what could be known.

In his work, both at his office, and at home, for instance when he was engaged upon making some piece of apparatus, or was cleaning some instrument, he was methodic and precise, with the need to finish things well and never to leave loose ends. He did not like things lying around in disorder.

In political matters his attitude was liberal, and he felt attracted to socialistic ideas. Being a simple civil servant in a subordinate position, he did not like to go far. Also he was aware that usually there are many sides to each problem. He was not a member of a party, nor of a church.

He did not feel the need for close association with others, nor the need for faith in a personal God. He stood on his own, like my brother and I learned to do. Father never used the notion of sin. The Bible was put away from us, as father and mother judged that it contained matters which are not fit for childrens ears.

We had no religious education in the customary sense, but we were imbued with responsibility and mutual faith, by the atmosphere reigning at home. It was only much later, when I was a student in Leiden, that a chance remark by Ehrenfest, who once read to us Tolstoy's comment on Joseph's capitalistic activities in the service of Pharaoh, made me aware that one could look at the Bible from a point of view which had connections with current topics. My interest in it came later from the side of ancient history, when a modern translation of the Bible had made its contents much better accessible.

To come back to my father's attitude, he knew that we have to face the consequences of the deeds of other people as well as those of our own deeds, and that we must carry the burden together. Never would my father have said "why must this strike me?" He bravely accepted his share in troubles and disaster, and did not think himself as separate from his fellowmen in this respect. He was never afraid of death and saw his end coming as a rest, for which he longed after the terrible experiences of the last year of the second world war (he was nearly 84 when he died on August 8, 1946). He did not ask for assistance from a minister, being true to his own ideas until the end. In all this my father was not dogmatic. Perhaps it was sometimes more a fancy than a reality that he believed always to be open for argument, but he certainly taught us to be open minded, and I know that the best teachers for young people must themselves have a strong belief in what they say. As to me, I am too often aware of all the complexities and alternatives which are present in any situation, to be a successful teacher of young people. I am apt to explain too much and leave the burden of the decision to others.

My father was always honest and scrupulous in his dealings with other people. That this formed a part of our education, will be understood. He taught us respect for the civil service which is needed to run a country, as well as respect for our teachers. He had an aversion for anything that was showy or pompous, or even purely ceremonial, in which he could not see himself as a performer. Perhaps there was an element of shyness in this. Nevertheless, he took care not to hurt anybody, and he was not attracted to the role of a fighter. But he was carried on by a sincere idealism and respected all mankind as forming one great community. Our education was not directed towards patriotic feelings or towards some conventional loyalty, but towards a cosmopolitan outlook. We never were taught to consider a symbol as more important than humanity.

The best of fathers friends, those to whom we owed much in our education, shared these ideas. How great a shock came to all of us in August 1914, on the outbreak of the first world war, can perhaps be imagined.

I have kept from my youth an utter lack of feeling for ceremonial performances. In certain respects I am more reticent than my father was, who could be very convivial.

Sometimes I can understand (on theoretical grounds) that a form of ceremony will add to the meaning, say, of a reunion of people who have come through a struggle together, as was the case in the Netherlands just after the liberation in May 1945.

On such an occasion I might even be able to express in words something of the thoughts which bind us but on the whole I find it difficult to see myself as a part of it. Also, for giving a speech, I am apt to be too concise, too brief; I cannot elaborate on such matters.

We had music lessons, piano, and for my brother later the violin (father and mother had used to make some music long ago, when we were small children). I have never learned to dance, and connected with this in some way is that I cannot give myself with ease to something in which emotional feelings would take the lead over thinking. I sometimes have the feeling that when I should become very angry with somebody, I might lose my selfcontrol.

So far in these pages I have mentioned my mother only a few times, but it must be understood that there has been a deep reaching influence from our mother's side in the development of my brother and me, which, however, is harder to describe than the influence of my father. Mother was three years older than father, being born October 5, 1859. She came from a family with some intellectual standing. It was a tradition in her family that in every generation there was one who studied theology and became a (protestant) minister. A cousin of her, whom I have known quite well, was doctor of medicine and had the position of inspector of public health in our province; he visited us from time to time and often talked with father about micro-organisms. A brother of my mother was surveyor. And mother herself, although her school education had not been much more than father's, had a very intelligent mind and was clear in her thinking. Mother made the home to be the place where it was safe for us to live, and where all our relatives were glad to make frequent visits. The fact that my father and mother lived in a way different from others, did not set them apart. And though amidst our relatives we were materially the poorer, I think most of them sensed that in our home there were things which were not so richly present elsewhere; interesting talk by my father, who was liked and even admired; things to be seen and heard; and hospitality and sympathy from my mother, who was a lady in every respect, who attracted everybody by her natural distinction and charm. She always had tea or coffee for everybody. She ensured that there was an atmosphere of comfort for those who visited us.

My mother was deeply devoted to father and to his ideals; she helped him fully and unconditionally, to such a degree that she sacrificed most of her own feminine desires and ambitions, wishing no more than to live with him and see through his eyes, so that father's program of life might be realized. She gave great care to our household; everything was attended to and all was neat and clean; she worked hard, and, as far as we could know as boys, everything ran smoothly. She was very apt at needlework and had been an assistant in a shop for needle work and the like, during several years before her marriage.

The meagreness of my fathers salary made it necessary that she sometimes undertook embroidery work for others (she embroidered the gold lettering on several banners for a corporation in Arnhem for scanty payment, as none of these corporations were rich).

With all this she kept a definite refinement in our style of living, and always had a keen interest for everything that reached us. It is only much later that I have understood something of the sacrifice our mother has made. In the picture which settled in my mind, the image of my father who certainly was an exceptional man takes such a large place that it puts my mother somewhat in the shade, but she also was exceptional.

During many years my mother, who had a good handwriting, wrote a great deal of the notes which father used for his lectures, and she took part in the things on which he was working. This had been a constant great joy to her in those years. Later on, much, and gradually all, of this work fell upon me, and partly also upon my brother (we often made drawings for father's lectures or helped in the making of instruments). Mother then lost her place at father's table, opposite to him; that became my place and she remained more in the other room, the living and dining room.

To give some idea of my mother's influence, I would mention that father was not deep emotionally.

He even had a certain intellectual limitation (perhaps a characteristic of the later part of the 19th century), which took for granted that reason would pervade the world. He was not aware of the possibility of far reaching mental strains, for which he had no understanding. Emotionally mother was a much deeper personality, though she forced herself to suppress much of this. I believe it is from her that I have inherited a desire to look for something beyond the evident outward appearance of things, in particular when I am moved by a landscape. I cannot find back where this originated, although I have some recollection of the enthusiasm mother could express when she saw a view which extended into a distance and suggested depths beyond human reach. Mother also loved flowers and could be very much impressed by the unexpected find, of a wild flower. These strands of feelings have come to some fruition in myself only later, through influences of my first and of my second wife, but the roots certainly go back to my mother. I still am moved by a view through trees, a little violet in a forgotten corner, the call of a bird, the stars - these are the privileges which one can enjoy as a pedestrian who can look around and listen. My brother has been deeply impressed by mother's personality; I think that in his case it is her image which always comes first.

As a child my mother had received a religious education, but she abandoned all connections with a church through fathers influence. She often told me that she had known the feeling of missing something, the singing in particular, which can be so helpful to give a certain outlet to one's feelings. She often told us about her youth - owing to the early death of her father, she had spent some years in an orphanage; she spoke about the boys she had known, and about the minister who gave religious instruction and for whom she always retained a great respect.

Most of our relatives were on mothers' side, and there were many nice and convivial people among them. I must mention, however, that father had a sister, five years older than he, who was a widow from the times from which I have recollection. She lived in Arnhem, not far away from us, and my brother and I (and also the boys about whom I shall speak later) visited her often. She loved all of us and spoilt us sometimes a bit.

As I mentioned before, I have been educated without any church connection. It is only in later life that I developed interest in religious matters and obtained some understanding for their importance. I cannot believe in a personal God and I never feel an inclination to pray. What I possess as religious feeling probably comes from my mother, although there is in it a part derived from my father's idealism and, if I may say so, from his mental courage, reinterpreted in a way which grew up in my own mind. Here in this country (the United States) my wife and I have become members of the Unitarian Church in College Park.

When father had to retire from the post office in 1913 as a consequence of insufficient health (he had twice suffered from pneumonia, and was overworked by the heavy work at the post office and troubles with the customs people - father, belonging to the postal service, had to act in the interest of the addressees of the parcels, whereas the customs officers acted for the government), his pension was small. Our household, however, was held up by the fact that several boys boarded with us, for a part boys whose parents lived in what were then the Netherlands East Indies, where secondary school education was scarce.

The first one of these boys had come already in 1904. Father also received some money for his courses, but that was not a large sum, and would have been grossly insufficient for the household. Moreover, part of it served for buying instruments and appliances. About 1913, I myself and my brother were already earning some money by giving help and advice to other pupils of the secondary school, who could not keep up with school and home work.

Father was considered to have a good influence on the education of children and he gave much time towards taking care of their school work and their behavior. Father loved children and could keep discipline, without becoming too exacting; he could be very playful and always had attraction for them. This now formed one part of his occupation, the other part being his own studies and his lectures. In retrospect I think that father's attitude with regard to child education was somewhat naive, and directed exclusively to the intellectual side and good behavior.

Father certainly had a good influence upon children but he had no deep understanding for difficulties from which children may suffer. I must observe that in that period, now 50 years behind us, educational problems on the whole did not go as far as they reach now; life still was somewhat simpler and children were more inclined to accept discipline.

What I must stress, is that the burden upon mother was very great. She also gave her love to all the children, in particular to the first ones who came, and both father and mother did their utmost not to make any difference between us (my brother and me) and the other children. But we had scanty domestic help and there was a lot to do in cooking and in taking care of the house, in mending clothing, etc. Domestic appliances were much less efficient than they are now, and always the amount of money that could be spent had to be calculated. Moreover, it was mother who always first felt the impact when we boys were quarreling or fighting. It also was mother who carried on the correspondence for the parents of the children,(who lived in the East Indies), and who mostly talked with teachers or the principal, when there were difficulties with the progress of the children at school.

(I may mention that also when we were away from home at the university, and later when we were married, it was mother who always wrote letters to us; father's contribution usually was a loving greeting with the words "mother already has written everything".

As I mentioned, the first boy from the East Indies, AFE Jansen, came in 1904; his brother, TV Jansen, came about 1907. Their coming has had a very important effect for my brother and myself. Before this the highest position on the social scale which was seen for us, was to become a schoolteacher (some of our female cousins, who were rather bright, went that way), or perhaps a surveyor or something like that. However, the father of these boys desired them to go to a secondary school, and as the first one did not differ much in age with me (he was 10 months older, but we were in the same form), it was then made possible that I should go with him, and that my brother should follow in due time. This was a first step ahead. It then happened that teachers and the director of the secondary school gave advice and help, and gradually it became understood that we might look forward to scientific studies.

The two boys Jansen whom I mentioned, have become very close friends to my brother and me. The older one has studied mechanical and electrotechnical engineering, and for many years has been conservator for metallography at the Technical University in Delft.

He took an important part in the programming and arrangement of the new laboratory for metals which was opened in 1961, where my brother now works. The younger brother is now acting director of the Museum for Ethnography in Rotterdam and has an extensive knowledge of Western American Indian peoples, and of the peoples of Polynesia. Both of them have more than once expressed their indebtedness to our parental home. I am sure that also the other boys, and the two girls who later on have lived for some years in our parental home, still think back to those years with much pleasure and gratitude; in this home everybody got something which he could take along for his life.

The last boys left my parents home about 1926. For father and mother there have then been some quiet years, which they have both enjoyed. Also my mother found much pleasure in this period of freedom.

I believe she still has taken care of a collection of butterflies which somebody had presented to my father.

In the fall of 1929 an illness manifested itself, which became more and more serious, and which has clouded mother's last years. She died in October 1931.

My father since then lived alone with a lady housekeeper, amidst his collections and his friends, and we regularly visited him. In 1940 came the disaster of the second world war and the occupation of the Netherlands. Father could manage, and we still came to him each year for many short periods - until the airborne American attack upon Arnhem in the fall of 1944. Then father and his housekeeper were evacuated. For three weeks they straggled around; finally they were picked up through the Red Cross and we could bring them to Delft where they stayed with us until August 1945, after the liberation. Father then returned to his house in Arnhem, with his housekeeper, but much had been destroyed and parts of his collections and instruments had been stolen (the collection of historical microscopes had been rescued through Government services).

Much of the city was gone and several of our friends were no longer alive. Gradually father's forces diminished, from a kind of bodily and mental exhaustion until the end came in August 1946.

I will insert here three quotations from letters which my brother and I received after our father's death.

(From Dr. B. Meilink, Principal of the secondary school in 1948, and teacher of physics in the years that my brother and I were pupils there) :

"I never met anybody, not even amongst the very greatest, who had such a genuine enthusiasm for the natural sciences with respect to all new things which were discovered and to all new points of view which came to the foreground. He was so full of admiration for the grandeur of nature and the infiniteness of the universe, that it gave warmth every time you heard him speak about it."

(from Professor dr. AA Pulle, professor of botany at the University of Utrecht, who was born in Arnhem and had known my father when he - Pulle - was a boy) :

"During the last days I have thought rather much of the olden times when your father and mother lived in the Gravenstraat, where the oldest of you was born on a winter evening. It was on the 13th of January; it must have been about 1895. A short time before I had made your father's acquaintance.

At that time he had a primitive microscope (it must have been a good microscope, the one my mother had given to father, from the firm of Reichert in Vienna, Austria - JMB) and with great enthusiasm he looked for all kinds of micro-organisms. It was then that for the first time I saw diatoms (I am inclined to believe that this has been of influence for AA Pulle's later career; he also came from a modest family, where the mother, a widow, was teacher of needlecraft at one of the schools in Arnhem as she was a friend of my mother's - J.M.B.). Afterwards he has moved to a different quarter of the town, and then turned more to physics. The man was a wonder; what has he not attained with simple means and how great was his rare enthusiasm.



JM Burgers at his farewell
reception (1955)

My oldest boy, who came back from the East Indies a month ago, once stayed for a week in your home when he was a pupil at the secondary school, and even now he still could tell about all he has seen and experienced during that week."

(from Professor dr. JH Oort, professor of astronomy at the university of Leiden and a great friend to my brother and to me) :

"I have always felt a great admiration for your father. As I wrote already to your brother, I felt in him something of that which the apostles must have possessed, a an inner, simple, but unbreakable, strong faith, which radiated through the whole of his life so far as this was visible to me. There was no other such a man in Holland."

I will attempt to give an impression of my parents's home as it must have looked to a visitor. To my regret my memories no longer are precise. In August 1944 (now almost 18 years ago I saw it for the last time in the state it had had for a long period. But during that period I had no more looked at it with fully the keenness of interest it deserved. Since I had left home for the University (October 1914), there gradually developed differences in outlook between myself and father.

This was a natural result of the expansion of my horizon and of interest in matters where I wanted to think independently. Also I married; my wife and I were very close in our thinking; we built our own life, and while father felt very strongly bent towards me, I had the need to be more detached from him. The same was the case in my second marriage, after the death of my first wife. When we came to Arnhem and stayed with father and mother, or, after mother's death, with father, it still was a very interesting environment, but I did no longer feel it as my environment, and even the collections of instruments, of minerals and shells, were no longer in the center of our interests. We also knew that it would be impossible to find room for all these treasures either in our house, or in that of my brother and his wife. I have no recollections of the apartment where I have been born, but I remember much about that to which father and mother moved in 1897. It was an apartment upon a second floor (American reckoning), without a garden, but with an attic. Much of work has developed here, and I believe that here also began the cooperation with his friends. As long as I have known there were already many instruments for electricity, at least two microscopes, books, and some minerals (although at that time father did not know much about them). Much of fathers photographic work started here. In 1906 we moved to a larger apartment, which had a basement, living rooms on the first floor, and bedrooms on part of the third floor and the attic. There was a small garden, although without much sunshine, but still so that mother, who loved gardening, could grow some flowers.

We lived there until 1913, and it was in these years that father's activity was at its greatest. In 1913, when father had already leave of absence from duty as a result of insufficient health, father could buy a house with the help of some friends who lent money; this house again had a basement, a first floor with two large rooms and a smaller one; a second floor with two large rooms and two smaller ones; and a third floor with bedrooms and an attic. The kitchen, both in this house and in the previous one, was in the basement; as we had dinner in the living room, everything had to be

carried up, while the dishes had to go down again (there was no kitchen elevator). The 1913 house had a little garden which was better situated than the former one, and mother enjoyed very much that she could do more in it.

When a visitor should come in, in the 1906 house or in that of 1913, and was ushered into father's study (the front room on the first floor), he would see himself at once amidst cabinets with various instruments. Rooms in houses of this type in Holland had high ceilings and fairly large windows. In the middle of the room there was a large rectangular table; father had his chair on one side of it (opposite to the chimney; other chairs around the table were for us or for the visitors. Behind father's chair against the wall there was a large double set of bookshelves, with many books, and also sets of drawers with mineral specimens or shells, for which I had made the little cardboard trays and the labels. On the bottom shelf stood many boxes with father's slides (old standard size $3\frac{1}{4} \times 3\frac{1}{4}$ inches total number over 1000).

Against the other wall (to the left and the right of the chimney) there were two cabinets with instruments. I believe one had as its lower part a set of large shelves, where drawings and prints were stored.

Between the two front windows (to the right from father's chair) stood a (Toppler-Voss) electrical machine, in a casing by itself. Father was accustomed to let it run from time to time with a hot-air motor, to produce little sparks "in order to have ozone in the room" which father believed to be refreshing. Somewhere around were pieces of quartz with crystals, and boxes with glass covers, containing minerals and fossils (other specimens were stored in a room in the basement. On the table there often was a jar with ditch water containing algae, the common polyp (*Hydra viridis*), daphnia's and other microscopic living beings, and also a microscope. Sliding doors (to the left from father's chair) connected father's room with the living room, where mother usually sat. The sliding doors were closed when father gave a course, and a screen for projections could be unrolled before these doors. Sometimes the projection apparatus had a fixed place on the table ready for immediate use; later on it usually was put aside and had to be brought out for the occasion. A large map of the Moon, in a frame behind glass, hung above the mantelpiece (opposite to father's chair), which map I had made for father. As it had been too much work to put in all the lunar craters, it contained only a selection; but it had all the maria, colored in red, and at that time I was rather well versed in the geography of the Moon.

Suspended from the lamp (above the center of the large table) was a magnetic needle which could swing in the vertical plane, indicating the inclination of the Earth's magnetic field. At times there stood on the table a little motor with clockwork for rotating cardboard disks on which we had painted all kinds of designs; these merged together for the unaided eye when the motor was speeded up, but presented a variety of interesting patterns when viewed in the darkened room by the intermittent light of a Geissler tube, connected to an induction apparatus with hammer interruptor. Somewhere a Crookes' radiometer was rotating, if the Sun shone upon it.

In mother's room, the living room, there was also a large table (for many years we had an oval table there), for all the boys who sat together at meal times, or were busy on their schoolwork. Along one wall there was a sideboard, and against the other wall, on both sides of the stove, some cabinets with mother's books and treasures (mother had a lovely little collection of erotic teapots), and the piano. The mantelpiece had a large mirror, and there were some pictures on the walls. From this room sliding doors led into a veranda or porch, closed in with glass where mother had many flower pots, and a table at which she could sit in the summer. There was no room which mother had just for herself. From the veranda, steps led down into the garden.

The visitor, after having had tea from mother, then was taken upstairs (this refers only to the 1913 house), to be shown into the museum room, which was above father's study. Here a lot of other instruments were on display in glass cabinets. There was the collection of historical microscopes, which included a hand microscope made by Musschenbroek in the 17th century, which father had rescued from a basket of rejected instruments from the old Physical Society in Arnhem (this Society had come into financial difficulties about 1902, and its collections were sold, mainly to the secondary school in Arnhem; but there were "left-overs").

There was also a large "solar microscope" and several instruments from famous 18th century and 19th century makers. In 1913, if I am not mistaken, father had bought, on a sale, a collection of acoustical instruments, with organ pipes, Cagniard Latour's siren, tuning forks of all sizes and pitches on large wooden resonant boxes, Helmholtz resonators, an apparatus to show Lissajous' figures with the aid of oscillating bars having various cross sections, etc. But we never have become at home in acoustics so much as we did in electricity, as this collection came when father, although still very active, was somewhat over the height of his desire to absorb new domains.

There were also various "curios" and in later years father often was presented interesting objects by acquaintances. There was, for instance, a tusk of a walrus with beautiful carvings, which had come from Eastern Siberia (Nizhny Kolymsk), and a collection of pieces of amber with insects (both of these are now in possession of my brother). There were many pieces of agate, cut and polished; a beautiful cameo shell, a set of ivory chess pieces, but much of this has been stolen during the period of evacuation of Arnhem. There were also interesting old books on shells (I once bought a whole set on a book sale in Leiden), and a copy of Rumphius "Amboinese Rariteitenkamer", a famous book on marine animals and shells of the East Indies, printed in 1705 (most of these books are with my brother now).

The room on the same floor above the living and dining room in the 1913 house, was the study room for the boys. On the third floor were the bedrooms, although father and mother had their bedroom on the second floor in one of the smaller rooms. Cold water came to the second floor (in the 1906 house it came at first only in the basement; later a tap was installed in the corridor on the first floor.

Water had to be carried up and down to the bed rooms on the higher floors. How much household work this meant, can be imagined. Mother had some help, and we, as well as the other boys took part in some chores, but this was not extensive.

To come back to father's study, I do not remember where the big Wimshurst electrical machine stood in its four glass disks. It has been sold, like some other instruments, to a school in Eindhoven, already much before 1940. Little electrical motors of various sizes, steel magnets of various dimensions, electromagnets, galvanometers, induction coils of the Ruhmkorff type with hammer interruptor, Leiden jars, Geissler tubes, all such things were to be seen. For the years before 1931 the source of electric currents was galvanic piles, Leclanche for weak currents, and potassium bichromate plus hydrosulfuric acid when stronger currents were required. The mixture had to be prepared periodically, which always needed great care in mixing the acid with water. Some months after we had moved to the 1913 house, we got electric light (there was not yet a cable through the street, but it was put in, just for this occasion); we then could use lead accumulators, which were charged by inserting them into the circuit for the light. We also used a set of old fashioned carbon filament lamps, which admitted one Ampere each. It will be understood that father always had lots of auxiliary materials, tools, nails, screws, tin foil, copper wire of various thickness, ebonite, paraffin wax, wood, paper in various sizes, and all kinds of odds and ends. Father never could reject anything which still, might turn out to be of some use.

After father's death, in 1946, my brother and I had to clear the house rather in a hurry, as it had to be sold so that it could be used by other families. There was much we had to throw away; in a sense this was a tragic end, but the more important objects which still were there, got appropriate destinations. Our own houses were not capacious enough to store all the objects (and sometimes the junk) which father had collected; moreover, both of us had already stored much in our houses. Some books and a few instruments were sold or given to father's last friends. The collections of minerals and shells went to our secondary school. The most important books were kept by us. The furniture was old fashioned; there was much which people nowadays did not like to use, or could not use, since modern houses not have such large rooms with high ceilings. So the house came to an end - it still lives for a large part in our hearts.

There still is a point deriving from my father's influence upon me, which I 'could mention here. I have said that he was an excellent teacher. He had a healthy naturalness and soundness about himself, and he never sought to overawe anybody by a show of learnedness. He always genuinely tried to make others see what he had understood himself, and known the difficulties he had had to overcome in this he had understanding for those of others. The courses he gave, started in our home.

It was his gift to explain phenomena, say of electricity or of light, to people who were not educated in physics. He did this from a desire to communicate to others the joy he had found himself in mastering any topic. For this purpose it was not necessary to go to far outlying fields : joy of understanding is possible with respect to the simple

beginnings of a science. And the people around us liked to understand. They came to father for that purpose. My teacher of classical languages, for instance, liked to listen to explanations and to argue about them.

There were at that time a number of scholarly educated people in Arnhem and its neighborhood. Many of them were members of the local Physical Society, or of the local branch of the Netherlands society for Natural History. At the meetings of these societies we could often listen to very interesting speakers, for instance on radioactivity, or on the formation of the coal fields, and I still remember that once the reversal of the yellow sodium line was shown on the screen with a projecting spectroscope. There were also certain gentlemen who had extensive collections of butterflies. Others did biological experiments. The circle of people amidst whom my parents lived, including our relatives, would deserve a special description.

There was also available a good fund of serious popular and semi-popular books and journals on scientific subjects, some of them translated from the German, others original productions by enthusiastic writers and editors in Holland.

When I came to the secondary school, I gradually began to catch up in knowledge with father, and then got beyond him, as the secondary school brought algebra, geometry, trigonometry, etc, and a fuller course of physics (and chemistry) than my father had mastered. But father still was studying himself, and we were in the habit of talking about what we had read, and of arguing about it.

A great event for us was the appearance of a very good translation of the book "The New Knowledge" (1908), which opened our eyes to the phenomena exhibited by ions and electrons, and to those of radioactivity. It was a kind of revelation to us, bringing a lot of information and order concerning topics about which we had heard only in a vague way. We then learned how one progressed from Geissler tubes for electrical discharges to tubes exhibiting cathode rays, and father soon got a whole new series of demonstrations under way.

Later on, when I got ahead of father, I still sought to translate my further knowledge into terms which could be captured by him. This remained so, when I came to the university and learned about quantum mechanics, then in its first stage, with Bohr's electron orbits around the nucleus. It came to my mind that a layman has no difficulty to accept that there exists only a set of discrete orbits. The notion of classical mechanics, according to which every orbit should be possible depending upon initial conditions, is rather an anomaly for a logical mind, looking for order and not having been subjected to training in differential equations.

The experience gained in this way has given me the conviction that every term, every notion and every equation used in theoretical physics, belongs to the set of ideas which are common possession of all intelligent and interested people.

Every physical notion is linked to other notions and these again to further concepts, and ultimately they have all arisen from the desire to give an interpretation of concrete observed facts.

$$u_t + u u_x = \nu u_{xx}$$

The famous Burgers' equation

It is only the extreme length of the chains of reasoning, which cause the difficulty for a mind not trained to absorb such chains and not acquainted with the mathematical way of presenting chains in shorthand form.

For a physicist working in the front lines it is often too cumbersome to look for a translation of newly conceived physical notions into common terms. Nevertheless, I believe it should be the task of every scientist to give some attention to the translation of his concepts into terms which make their meaning clear to non-specialists. The ultimate object of science is not its use for technical performances.

Its ultimate purpose must be to expand the world picture shared by a large group of people, and to bring to them the joy of understanding. At the same time we should take care to point out the limitations involved in the scientific picture, resulting from its abstraction from values which sets it apart from much that is contained in life when viewed in its fulness.

Before closing this chapter and passing to school education, I would look back once more towards the atmosphere of clearness and of reasonableness, which we believed that existed, before 1914. I mentioned that we made many walks around Arnhem; there was a connection between what we received at home and what we enjoyed in the open air. It laid the foundation for a deep love of the Earth and of the life its carries. It was a time when public transportation was measured to the needs of the excursionist and the pedestrian when there was much less traffic and far less noise

on the roads and when there was not yet the terrific expansion of the population, in numbers and in mobility, leading to the deterioration of the countryside by continuous building of new groups of houses, of roads for heavy traffic, or by 'opening up" recreational areas.

Something of the atmosphere of this period is pictured in a novel by JB Priestley, "Bright Day" where also a group of old and young people is described who liked to walk. Much of this background of our life vanished with the first world war, although parts of it still could be recaptured in Holland for many years after 1918.

Both with my first wife and with my second wife I have often come back to Arnhem and again we made long walks. With my second wife, during the years 1942-1944. I even got a much better idea of this part of the country since we covered larger distances and had maps who explained the character of the landscape and its geology.

Some parts of the country around Oosterbeek even now are still as beautiful as they were 50 years ago, as I saw on a trip with my brother in May 1961.

But it is a curious experience that I believe to have found in America, for instance in Maryland, some of the features and the moods which I absorbed in my boyhood. When coming to the new continents, I have kept open the "eyes of discovery", as an explorer who is elated by the landscapes and the new kinds of flowers amidst which he now can move around. This is a constant joy to me which makes me feel at home here.

BEREKENING VAN HET VERLOOP VAN DE STROOMINGSSNELHEID EN
VAN DEN DRUK LANGS EEN DOORSNEDE VAN EEN SCHOEP VAN EEN
WAAIER MET 5 SCHOEPEN VAN EEN DER CENTRIFUGAALPOMPEN TE
MEDEMBLIK.

Rapport opgesteld door J.M. Burgers en B.G. van der Hegge
Zynen ingevolge de opdracht van de Directie der Zuiderzee-
werken, verstrekt bij schrijven No. 3162 dd. 18 Augustus
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TABEL III.

LOGARITHMISCHE AFBEELDING VAN DE SCHOEP, OVERGEBRACHT IN DE
COÖRDINATEN ξ, η .

θ°	BUITENZIJDJE		BINNENZIJDJE	
	ξ	η	ξ	η
0,22	+ 175,0	+ 0,8	+ 175,0	+ 0,8
1	+ 169,7	- 2,2	+ 168,2	+ 2,8
5	+ 138,0	- 3,1	+ 135,2	+ 4,9
10	+ 98,3	- 4,3	+ 94,1	+ 7,8
15	+ 58,7	- 5,9	+ 53,1	+ 10,3
20	+ 19,3	- 7,9	+ 12,4	+ 11,9
25	- 20,0	- 10,3	- 20,1	+ 13,1
30	- 59,1	- 13,8	- 68,5	+ 13,9
35	- 97,8	- 17,5	- 108,9	+ 14,5
40	- 136,7	- 20,8	- 149,2	+ 15,1
45	- 176,0	- 23,2	- 189,7	+ 15,4
50	- 215,8	- 24,1	- 230,2	+ 17,3
55	- 256,1	- 23,7	- 270,6	+ 18,0
60	- 297,8	- 19,0	- 310,3	+ 17,0
61	- 306,3	- 17,7	- 318,2	+ 16,5
62	- 315,0	- 15,9	- 326,0	+ 15,8
63	- 323,7	- 14,0	- 333,4	+ 14,0
64	- 332,4	- 11,7	- 340,4	+ 11,0
65	- 341,3	- 9,2	- 346,7	+ 6,3
65,63	- 348,5	- 0,8	- 348,5	+ 0,8

In this section I will speak briefly of influences emanating from school during the period I lived at home; then I shall pass on to the years at the University of Leiden, and the beginning of my career in Delft.

My brother and I had our primary and secondary school education in Arnhem at the city schools. Primary education was from the age of 6 to 12, secondary from one's 12th to the 17th year. The schools were very good. It is interesting to mention that we wrote on slates in the lower forms. I still remember the series of pictures of three quarters of an apple we made when we were engaged upon the multiplication of fractions. French started in the fourth year. We had much homework. I also think of the geography we had to learn, in particular from the European countries: series of mountain chains in France, the system of canals by which one could go from, say, Strasbourg to Paris, and the cities you met along important railroad connections from one country to another. History brought all the wars in which William the IIIrd has been engaged. We also learned the grammar of our own language, and quite a lot of French grammar, with irregular verbs and the rules for the *Passe defini* and the *Subjonctif*.

In 1907 the older of the brothers Jansen and I passed the examination for admission to the secondary school, the "Hogere Burgerschool", with a five-year course. My brother came two years behind us, owing to the differences of our ages. After we had passed the final examination of the secondary school in 1912, the older Jansen went to the Technical University in Delft, while I stayed at home during two years for an abbreviated course in latin and greek, which at that time was still necessary for admission to the other Universities, for which one had to pass a special examination. These languages I learned under the guidance of Dr. F Wolf, a teacher of classical languages at the "gymnasium" or classical school. He was a scholar with a wide interest in literature and he knew sanscrit. He has never asked any payment for the time he gave me. During the same period (1912-1914) I daily went to the village of Velp to help a pupil of the secondary school with his home work, in order to earn some money; and I studied mathematical and physical topics.

We had excellent teachers at the secondary school. While in those years not directly preparing for university study (although it opened the road to the Technical University), the school furnished a good and extensive all round education, including mathematics (without calculus), physics, chemistry, natural history, geography, history, literature, the three foreign languages (French, german, English) with summaries of their literary history, economics, an introduction into political science, drawing. We read Moliere, Racine and other French authors; learned about Shakespeare, Milton, Dryden, Goldsmith (we read the "Vicar of Wakefield"); and learned about Schiller, Goethe, Lessing and other german authors. Dicken's novels I read at the time with my father in a dutch translation. For many years I have remained in close friendship with several teachers and with the principal (director), Dr. H Hulshof. It was later that I learned that Dr. Hulshof was engaged upon the elaboration of a kinetic interpretation of the thermodynamic potential.

His doctor's thesis had been on the theory of the capillary layer, for which he had proposed the notion that the pressure in this layer was anisotropic.

This idea had found much encouragement from the side of his professor, the well known (older) van der Waals. In some way, however, there has arisen a difficulty about it with Dr. G Bakker, who is better known in the literature for his work on the theory of capillarity. It was Hulshof's conviction that Bakker had heard about it through van der Waals, and had worked it out rapidly and then presented it more or less as his own idea. Knowing the probity and the intrinsic modesty of Dr. Hulshof, I am inclined to believe that he was right. He may have been thinking a long time about this notion of an anisotropic pressure and has been somewhat slower in bringing it into the open, so that Bakker got the start. A curious point is that Dr. Bakker was the teacher of physics at a similar school in the Hague, where my first wife has been a pupil. I became acquainted with Bakker at some meeting at Ehrenfest's colloquium; I believe, this was before I knew about the dispute between Hulshof and Bakker.

Our teacher for natural history in Arnhem, AC Oudemans, was a man with great enthusiasm and great knowledge. In his class room he had many collections, minerals, shells, butterflies, beetles, etc. and also cages with various living animals, all of which was kept in an excellent state. During 5 or 10 minutes before he started with the class, we - the pupils - were allowed to go around through the room and look at the animals, or at the collections in their drawers.

JM Burgers at work



Oudemans also had the custom to bring to our attention interesting matters happening around us, for instance astronomical occurrences, or the capture of an uncommon type of fish in the North Sea, etc.; for this purpose he had a bulletin board with clipping from newspapers or illustrated journals. He himself did scientific work on mites, and he was always busy when there was no class, and after school hours, either with re-arranging parts of the collections, or with the preparation of very fine skeletons, or with his studies on mites. He had also a taste for historical matters, and he wrote a big volume on "The Great Sea Serpent", in which he collected and reviewed all references to it throughout the ages up to modern times. His many volume work on mites (the publication of it was continued after his death from his extensive files of notes) started with all historical references to mites, from biblical times to the present. He permitted me to come every week, during an hour after school time, with a box of rock specimens or shells from my father's collection and helped me to find the names, which he either knew by heart or found out by comparison with the school collections. From Dr. Oudemans' textbook on natural history it was in particular the third part, on mineralogy and geology, which gave much information to my father and me. I remember that a short time after we had bought it, father, having become interested in the characteristics of the six crystal systems, made a set of neat models, from knitting needles (furnished by mother), drinking straws, cut into sections to form the axes, and threads to represent the edges of the main forms, all fitted together with sealing wax - which, as is well known, was an important item in the physicist's outfit sixty years ago.

My teacher of mathematics in the advanced years, Dr. C van Beek, lent me Holzmüller's book on extended elementary geometry. Dr. Hulshof gave me Ch. Sturm's "Cours d'Analyse", in which I have been working at the same time that I was busy with latin and greek.

Dr. B Meilink, the teacher of physics and later the successor of Dr. Hulshof as principal, who guided his classes with almost no effort and who inspired discipline by his natural and calm way of doing, lent me Maxwell's "Theory of Heat". I can still remember how I was puzzled by the chapter on the "Representation of the Properties of a Substance by Means of a Surface", which I could not understand at that time.

Later on he lent me Maxwell's "Treatise on Electricity and Magnetism". As will be understood, this contained much that gave me great difficulties, as e.g. the chapter on spherical harmonics, the title of which made me think of Kepler's harmony of the celestial spheres. Nevertheless, I got much out of the book, for instance on the theory of electric currents. Dr. Meilink also procured for me a set of lecture notes on mathematics and on physical chemistry from a student at the University of Amsterdam, which I worked through. Further he permitted me to do some practical physics at the school laboratory, as a preparation for university study; this gave me some relief from the course of practical physics in Leiden later on.

We had an excellent teacher for chemistry, Dr. B Holsboer, but although I had dabbled a little bit in chemical experiments, this subject has never attracted me greatly. I was interested somewhat in the formalism of organic chemistry, but all this was long before the modern theory of valence and of the various types of chemical bonds was developed.

At the same time there still was much material for study in father's books. There was, for instance, an almost complete collection of the volumes of a monthly journal "Album der Natuur", which in its later years (it stopped about 1912) brought papers with extensive digests of new subjects in various sciences, for instance on the phase rule and its application, on colloid chemistry on the early stages of the mutation theory. From one of father's friends I got two little volumes of the Sammlung Goschen on metallography, which gave more illustrations of the phase rule and from which I also learned about the texture of metals as revealed by the metallographic microscope. A volume of the then existing "Scientific American Supplement", which the father of the boys Jansen had sent to us had articles by RA Millikan on his exact determinations of the charge of the electron. In the journal of the Netherlands Chemical Society the extensive text was published of a lecture given by professor HA Lorentz on the various determinations of Avogadro's number (if I remember rightly, it was mother who directed our attention to it, having read about it in the newspaper).

From another friend I got the money to buy (second hand) the book "Meteorologische Optik" by JM Pernter and FM Exner. In this book I found a presentation of Airy's diffraction theory for the rainbow, to which Pernter had added an extensive calculation of the color distribution, for various droplet sizes, on the basis of a reduced set of Maxwells color equations. Since father and I were much interested in the polarization of light and its application to the observation of minerals in thin sections under the microscope, I started to work out a calculation of the interference colors which could be observed, e.g., with sheets of mica of increasing thickness. I wrote a descriptive article on polarized light for the semi-popular journal "Der Natuur", in which I gave the results of this calculation. The article was illustrated with several photographs of the structure of granite, basalt and other rocks, made by father with the polarizing microscope, and with drawings which I had made. It must have appeared, I think, in 1913. That I still liked to read on natural history, and in particular on the theory of evolution, will be understood.

We certainly shall have made many walks in that period, but I have no specific recollections. It is curious to note that, apart from some very brief visits on bicycle to Emmerich and to Cleve, two cities in Germany close to the border of our province, I had never been out of the Netherlands. We always looked at the international trains coming through Arnhem to and from Germany (often having cars for Switzerland, and sometimes for Genoa or Ventimiglia), and once or twice father made a project with me for a day trip to Koln (Cologne). But nothing came from that. Even in the Netherlands I had seen rather little, some of the cities of our province, not far distant from Arnhem; we had been several times in Amsterdam and in the Hague, and in a few other places, but that was all.

Although I had read about Germany and its geology, and had been presented collections of rock specimens from the Eifel, from Thuringen, and from Switzerland, I had never seen a mountain and the highest point near Arnhem (about 110 meters above sealevel) had been my limit of altitude. Father and mother had made a trip along the Rhine to Frankfurt, with a side trip along the Mosella; and they had been to Paris and to Berlin. I believe all three trips upon the invitation of one of mothers cousins and his wife. They told us often about these trips. In 1907 (?) they made a trip to Dusseldorf to see an exhibition of industrial products and machinery. Mother told us about a huge wheel, which went backward and forward alternately and also about the adventures of the return trip; they had taken passage on one of the Rhine steamers (still operating) but owing to fog the boat was delayed very long and they had to sit on the quay for the whole night, and were happy when a booth went open in the morning for market people, where they could get some hot coffee. Their honeymoon trip had been to Brussels and some other cities in Belgium. I have the impression that father had some difficulties with hotels, owing to lack of experience, but they must have seen the famous "Rocher Bayard" near Dinant on the Meuse and the cave of Han on the Lesse.

In May 1914 I had to submit to the medical examination for the military service. Fortunately I was rejected on account of a too narrow measure of my chest. I am very grateful that this has saved me from passing tedious years without scientific and cultural contact in military garrisons, when the first world war broke out in August 1914 and the Netherlands army was mobilized to protect the frontiers (which remained necessary until the end of the war in November 1918). My brother, and I believe also the Jansen brothers, were rejected for their eyesight.

I would add that my education in matters of art was not extensive. We liked to go to concerts and father knew the music of many operas. Some of his friends were good musicians. But father and even mother, had not much knowledge about paintings.

We had been in the famous "Rijksmuseum" in Amsterdam, and in the "Mauritshuis" in den Haag; but the classical paintings had made little impression upon me. We knew a bit about classical sculpture; father had some good reproductions from the masterpieces in the Louvre Museum in Paris, and our classes in literature and in drawing at school gave attention to art; but it did not come to my heart. It is only later, under the influence of my first wife that I began to develop more feeling in this direction.

There were some movie theaters in Arnhem to which we went rather often. The foremost of these theaters sometimes had a good scientific film as an item on the regular program.

I remember one on the microscopic living world, which was presented very well both photographically and in the way it was arranged. It must have been a french film, in 1913 or 1914, which thus appeared many years earlier than the films which the german firm of Zeiss brought out, to be shown before scientific societies, some years after 1918. In this french film even the strange spherical colonies of the alga Volvox

were shown. Father and I naturally were delighted to see the organisms we knew so well. I also remember a film of a valley in the french Alps, taken with a camera on the front of a locomotive with pictures of the villages and of the stations at which the train stopped.

Leiden (1914 - 1917)

After I had passed the examination in latin and greek in August 1914, father brought me to Leiden in the end of September to find a room (students boarded with private families, or lived in rented furnished rooms) and on October 1 I started as a student. In the home where I came to live there was in the first year also a Belgian physicist, Victor (?) Counson, who was following courses in Leiden.

The war, which was relentlessly going on, naturally always was in the background of our thoughts. Newspaper information as well as the mobilization of the army, and various measures which gradually became necessary to alleviate difficulties caused by scarcity of food, kept the war constantly before us. On very quiet nights (traffic had been cut down through rationing of gasoline) one could sometimes hear the gun fire in Flanders. When various revolutions started from 1917 onward, many of us were interested in their back ground and in the meaning they might have from the social point of view, whether they might bring improved conditions of living or not. But the study itself brought so many new things and few ideas that it was the university influence which holds the foreground.

I could now absorb much more than before at home, and I did this with eagerness.

I had come to the university of Leiden with very little idea how it was operating. The only names which had been known to us in Arnhem were those of HA Lorentz and of H Kamerlingh Onnes; I may have heard the name of a professor of mathematics, and of one or two in the department of classical languages. I was befriended with a student of mathematics, AC Elsbach (died 1932), and I went to him for information.

When I got a list of the courses and saw that Professor Lorentz would lecture at the Physical Laboratory (which I had noticed on one of the streets), I decided at once that I should attend his course. Lorentz had left Leiden for a position at a private institution, "Teyler's Foundation", in Haarlem (I shall come back to this foundation later), in order to be relieved from the duties of a regular professor and to have full time for scientific work. He was, however, "extra-ordinary" professor in Leiden and came every Monday morning for a special lecture. Hence, on the first Monday in October I presented myself at the Physical Laboratory (the famous Cryogenic Laboratory of Kamerlingh Onnes), where I was received by a gentleman (I think it must have been Dr. CA Crommelin, chief physicist), who turned me over to one of the workshop boys, and the latter conducted me through corridors with all kinds of complicated machinery and big bunches of pipe lines, through a small court, to a lecture room in a separate building at the back of the main laboratory.

While waiting in the class room, I saw two gentlemen passing on the outside, and immediately realized that one of them must be professor Lorentz, since I had heard about the knobs on his forehead, which had developed as a result of his constant

thinking. The other one, a dark looking man of somewhat smaller bodily stature, who accompanied Lorentz, later on appeared to be Professor Ehrenfest, his successor as ordinary professor of theoretical physics in the academic year 1914-1915. Lorentz lectured on "Interference and Diffraction of Light", a subject which I could follow without much difficulty, having read about it in an extensive dutch textbook on optics while still being at home.

University study in Holland was, and still is, very free, much more free than it usually is in the United States. Once having paid the admission fee for the entire university one could go to lecture in any department one liked (or also stay away from anything that one did not like); it was not necessary to have an official adviser and ask for permission to follow this or that course, or to change one's plans. One could follow a course in ancient Egyptian if one liked to do so, along with physics and mathematics. Every student at our universities is counted as a fully grown up person, who selects for himself.

I had physics from P Ehrenfest, JP Kuenen, A Lorentz and H. Kamerlingh Onnes; mathematics from JC Kluyver and Lator and also W van der Woude; astronomy from EF van de Sande Bakhuyzen and W de Sitter; geology from K Martin.

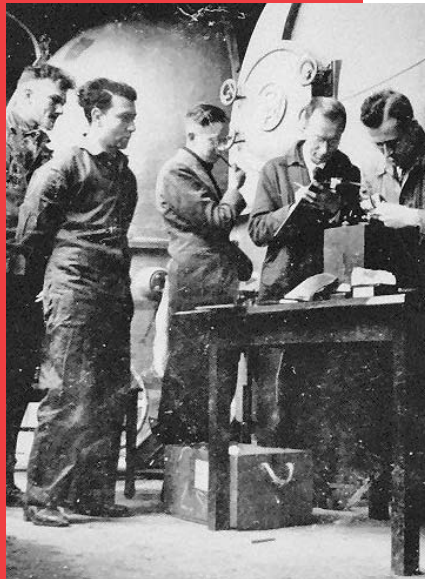
The lecture room for theoretical physics at the same time served as a special library for mathematics and physics with a complete sets of the Philosophical Magazine, the Annalen der Physik, the Physikalische Zeitschrift, etc. complete works of Cauchy and other mathematicians, of Stokes and of W Thomson, and a lot more.

For a small yearly sum one could become a member of the "Reading Room Bosscha", as it was called; it was not allowed to take books out (many of them were on deposit from the main library, and Ehrenfest insisted with us that all books should be always available in this room), but one could sit there and read and work. The number of students in physics and mathematics was small in those years. It was an extremely educative and stimulating situation; we always were there before class started and had books before us; usually we came also in the afternoon.

In this way one became acquainted with the "founding fathers" of modern physics and mathematics, as well as with the current media of publication. Ehrenfest had been the originator and was the spirit of the "Reading Room" having brought over the idea from Göttingen. It has been in existences for many years, but I am sorry to have heard that a later professor of theoretical physics has stopped it. To us it has meant an opportunity, of which we have profited greatly.

The fact that I came to Lorentz' course drew the attention of Ehrenfest. Soon he invited me to a lecture which he gave before the Chemical Society on Bohr's model of the atom - the first time I heard about it ! - and then he invited me to attend his weekly colloquium, which was held at his house. At this colloquium the current literature in physics was reviewed and extensively discussed.

It is Ehrenfest who has had the greatest influence upon my development and who introduced me into the spirit of real scientific inquiry in physics. Quantum theory was then in its first stages; the theory of special relativity had obtained a definit form a few



JM Burgers (second from right)
at his lab

years before, but, as I gathered later, there was still much to do about the tensor which should represent matter; in the years 1915 and 1916 Einstein gave the final shape to his theory of gravitation. The work of James Frank and Gustav Hertz on the excitation of atoms by collisions with electrons accelerated through a definite potential (1916 or 1917), was one of the first striking demonstrations of the correctness of quantum theory. The mass spectrograph had been described in principle already in RK Duncan's "The New Knowledge", which had come out in 1908; now, at one of the first colloquia which I attended I heard about the discovery of isotopes.

Ehrenfest made us acquainted with all these subjects, and let us also share in the development of his own thinking. He often needed one or other of his students to talk about some new idea, as he found this helpful to clear up his own mind. So he told me about the development of Einstein's theory of the gravitational field in 1916. Einstein was accustomed to send copies of the proofsheets of his papers to Ehrenfest every time a further article was in the press, so that Ehrenfest received the news before it actually had come out. Ehrenfest told us also about the conceptual difficulties which he saw in many theoretical investigations. He brought me into contact with other physicists in the Netherlands, as well as with the few foreign guests who came to visit him (the war prevented normal international travel). I remember G Breit and G Nordstrom; the latter was in Leiden for a long time and married Miss C van Leeuwen, student in physics somewhat older than I was. Einstein came in the summer of 1917; I remember that I was sitting with Gunnar Nordstrom in his room (opposite Ehrenfest's house), when Ehrenfest called at the window and told that Einstein had arrived, whereupon we joined in the reception. Niels Bohr came to Leiden not before 1919.

I also owe very much to a close friendship with three fellow students of that same period who had come to Leiden one or two years earlier D Coster (died 1950), HA Kramers (died 1951), both physicists; and DJ Struik, mathematician. Much understanding for the meaning of mathematics was obtained from talking with them, in particular with DJ Struik.

It was Ehrenfest who had introduced me to them; I believe this was even the first time that he invited me to his home. How much was I Impressed by his study, a large room with three windows in one of the walls, looking out on a part of the garden, and a large couch at the other wall, where I have been sitting so very often. On the shorter wall there was a large blackboard, a strange form of decoration even to me (it was in this room that also the colloquium met in those years). In the bookcases I saw many books, amongst them some russian books, and I remember Hilton's "Mathematical Crystallography". There were pictures between the windows at the wall, Boltzmann, who had been Ehrenfest's teacher in Vienna, Maxwell, Waiter Ritz with whom Ehrenfest had had a close friendship, but who had died young; Tolstoy, Dostoyvsky (of whom I had never heard) and one or two views from the surroundings of St. Petersburg, from which Ehrenfest had pleasant recollections.

To me this room has been more impressive than the study rooms of any other scientist by whom I have been received. It had a simplicity and austerity, and for me it

has a grandeur, since it speaks of the many chapters of modern physics which have been discussed in it, with Ehrenfest's colleagues as well with the many, many visitors that have come to see him. The room has spoken to me the stronger since

I was received there as a close friend, almost as a close relative while also my best friends were at home there. Soon I was also received in the dining room, which so often had full sunshine coming from the garden. Mrs. Ehrenfest had (and has) a very pleasant way of treating us, and of talking; she was almost as inquisitive as Ehrenfest was himself, and she often engaged us for work in the garden of which she was very fond. All this deepened the impression which I had from Ehrenfest's study room; I have found myself almost at home there as it had been in my father's house.

When I was in Holland in May 1961, my wife Anna and I visited Mrs. Ehrenfest, and we were again in the same room. I still am sensitive to its atmosphere and I miss Ehrenfest himself. There were many of the old photographs and of the books, which I had seen on my first visit in October 1914. If ever there would be some truth in the idea that walls do absorb something of the spirit which has reigned in a room, how much would these walls be able to give back !

I mentioned that Ehrenfest introduced me to some students in physics and mathematics, who became my closest friends. There existed in Leiden a "dispuut", a society of students interested in physics, mathematics, astronomy and chemistry, called "Christiaan Huygens", and I think that again it was Ehrenfest who mentioned it to me. Soon I was admitted as a member.

The society met every fortnight, from 7 p.m. to about 11 p.m., sometimes followed by a nightly walk. There was a longer lecture and a shorter communication, given by members, and often also a jocular improvisation on an assigned subject. The longer lectures were always well prepared and treated advanced topics taken from the field of study of the member who gave the talk. Often the talks went quite deep. Since questions and discussions were fully allowed and encouraged, the meetings were extremely stimulating. They usually were held in the room of one of the members, who had to arrange for tea and coffee, and for sweets, cookies, pies, etc. Coster, Kramers and Struik were members, as was also AC Elsbach.

The first time, when I came as a guest, I listened to a talk by C de Jong, on unsolved problems in astronomy. De Jong at that time was already working on a thesis connected with Kapteyn's theory of two star streams. I also became great friends with Marcel Minnaert, who came from Belgium in 1915; he originally was a biologist, but now studied physics and was later to become the foremost solar physicist in the Netherlands, successor to WH Julius. There also were some girl members, and it was there that somewhat later I found Jeannette Roosenschoon who came to Leiden in 1916 to study physics. She became my wife in 1919. (My second wife, whom I married two years after her death, was the sister of another member of Christiaan Huygens; she studied law. Thus all of us belonged to the same generation). A few times each year "Huygens" arranged walks or excursions; often Ehrenfest joined us.

My father enjoyed very much to become acquainted with the friends I had found in Leiden. Struik, Coster and Kramers also have been in the house in Arnhem. Kramers became very much befriended with my brother. Ehrenfest taught us how to read scientific papers, to look for the assumptions made by the authors, and to hunt them out when they were not given explicitly. His powerful analytical mind opened our eyes to many subtleties in physical theory. He always strove to find interpretations of new thoughts, and had striking ways for the illustration of their peculiarities. His method of lecturing consequently was unique.

He encompassed and taught theoretical physics as a whole, and in passing gave us insight into a good deal of mathematics bringing cross connections between domains which until then had looked as quite separate.

His regular courses were on Maxwell's theory and on statistical mechanics, but there were also special courses. A course on some aspects of colloid physics, developed into an expose of the probability laws for radioactive phenomena. A course on certain parts of theoretical mechanics developed into a highly illuminating survey of the theory of integral equations, in which Ehrenfest gave us a thorough introduction into what later became known as the theory of "Hilbert space" (1915). Although Ehrenfest did not introduce the projection operator the ideas gained from these lectures have helped me greatly when many years later I read Johann von Neumann's "Mathematische Grundlagen der Quantenmechanik". In a later year we had a seminar on linear partial differential equations of the second order, in which Ehrenfest stressed the relations between the various types of equations and quadratic surfaces.

I had to make many large scale sketches of various sets- of confocal quadric surfaces to illustrate the lectures (one of the sketches for many years has hung in the dining room of Ehrenfests house). He often let us give parts of this course. It was still in my first year, that, on one of the rare occasions that he was unwell, he asked Kramers and me to present Poynting's theorem on the flow of energy in the electromagnetic field. We were invited to his home the night before, in order to be properly briefed. I felt very glad to be asked to do this.

Ehrenfest gave constant food to my desire for understanding and he expanded the views and interests I had brought from home. No longer it was my father's maxims which took the first place in my thinking: Ehrenfest's influence became the stronger one.

Ehrenfest was fond of music, and was a good piano player. Sometimes he played for us. It seems to have been Einstein who opened Ehrenfests ears for Bach's Preludia and Fugues. Ehrenfest made me acquainted with several of them, which still are my favorites. I also remember one of Beethoven's Bagatellen", which he often played. Once he had a guest staying for some days at his house, who played Beethoven's "Sonate fur Hammerklavier" with its passionate and sombre "Adagio sostenuto". A few times Ehrenfest arranged some students to play Bach's Fugues in such a way that each voice was performed by a separate instrument, so that one could follow the tunes more easily.

I also vividly remember that on a morning in the month of May, after a class, he took us to one of the buildings in which the Ethnographical Museum in Leiden was housed in that time; in the garden there was, a set of five wonderful statues of the Buddha (still forming a famous treasure in the collections of the Museum, and now placed in a room of honor), standing under a magnolia tree in full flower, with bright sunshine over everything.

I mention these matters as examples of how much Ehrenfest contributed also to the development of our inner life. Ehrenfest, so to say, distributed all, that which was living and active in him. Sometimes it looked (I believe to see this now, from a distance), as if he gave away everything he had found or observed, without building up a reserve, a kind of stronghold, within himself.

I regret that I cannot give a picture of Ehrenfest as I could do of my father. He was of course, much more complex than father was, and also much more complex than I am myself. His analytical mind stirred up everything, so that at times it looked as if nothing would be left as it was. On the long run this pushed his students somewhat away from him and I have also experienced this effect. There were things which we did not like to have analyzed. It may look as if this betrays a lack of intellectual interest, but in several cases it was an instinctive protective reaction from our side. I can enjoy myself with things or in situations without asking whether they have a meaning, whereas Ehrenfest would question every aspects. Ehrenfest had a great personal sensitivity, which I have not always understood. He had a hunger for friendship as if he could not find a sufficiently strong anchor within himself.

There was some inner sadness in Ehrenfest, perhaps also a hidden fear, may be due to his Jewish origin.

I remember a meeting in the spring of 1918, which Ehrenfest had arranged to make physics teachers acquainted with recent discoveries. He asked some of us to give talks ; I believe I spoke on the work of Franck and Hertz. This meeting naturally gave him great pleasure, but what was strange to us was that he said it had given him more pleasure than the birth of his youngest child in that same year. This surprised us greatly. I have spoken about it with Lorentz and asked him whether he could talk with Ehrenfest, and help him to find a way back to feelings which looked more normal to us. But even for Lorentz it was too difficult to penetrate into the deeper recesses of Ehrenfest's mind.

None of us could reach deep enough, and each of us had already other problems before himself, which we wanted to consider and to keep for ourselves.

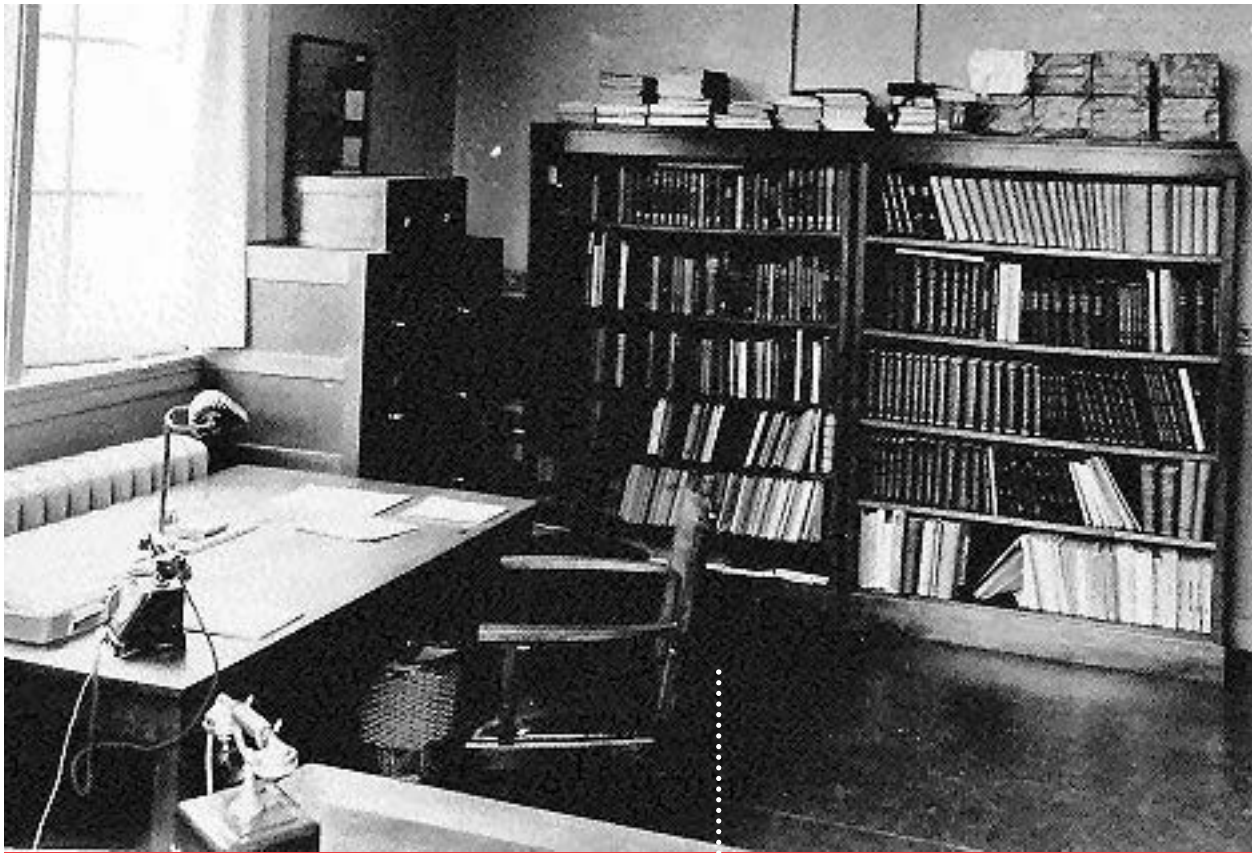
While we perceived that Ehrenfest's self analysis could take dangerous formats lead to utter despair, we could not help him. At that time I had already become engaged with Jeannette Roosenschoon and, while it had been Ehrenfest who had helped me to become liberated from my fathers world, the intimate exchange of ideas with her opened still another world for me. A world, it is true, not bringing them vista's of science, but bringing pictures of personal and social relations which were not less important for development.

We married in the summer of 1919, and it was with my wife that I strove to build up my place in Delft (see later on), and to form a picture of the new aspects in which Europe was presenting after the war and the various revolutions. Then Ehrenfest's influence lost hold, in a similar way as it had happened with my father's influence a few years before. Moreover, the colleagues whom I found in Delft, in particular C.B. Biezeno about whom I shall speak later, soon assumed an important part in my daily contacts.

It is probably also a result of a difference in mental attitude of more shallowness and a more formalistic attitude on my part in comparison with Ehrenfest's, that I cannot give a good picture of what was in Ehrenfest's mind when we struggled with the mysteries of quantum theory. The problem of the adiabatic invariants was an important topic. Ehrenfest had the conviction that here was a domain where classical mechanics provided an inroad into the new theory, and he strove hard to grasp the meaning of those cases where unexpected relations presented themselves as, e.g., when the oscillations of a pendulum increase in amplitude beyond 180° and pass into a cyclic motion. Another problem was how to count the various configurations of a mechanical system, say a gas with many molecules, so that the proper basis is obtained for the calculation of the entropy, as the most obvious way of counting required a mysterious division, by N to give the proper result. I had to leave quantum theory behind me when I went to Delft to occupy myself with fluid mechanics. I have no direct knowledge of Ehrenfest's first reactions to the work of Broglie, Schrödinger, Born Heisenberg and P. Jordano. The discovery of the electron spin by Goudsmit and Uhlenbeck has given him great joy.

To come back to my story the first important extension of Bohr's theory had come in 1916 through the work of Sommerfeld and Epstein on systems for which the Hamilton Jacobi partial differential equation can be solved by the method of separation of variables. In view of the importance of adiabatic invariance the question naturally turned up whether the quantities introduced by Epstein, the "phase integrals", would also be invariants. We were convinced that this should be the case, and I succeeded to prove this by the application of a set of transformations of partial derivatives. It was somewhat like solving a puzzle. A paper on this subject was accepted by Professor Lorentz for publication in the Proceedings of the Royal Netherlands Academy of Sciences (Ehrenfest became a member of the Academy in May 1919). After having given a proof for the general case without degeneration I could show that in the "degenerate case" the remaining independent phase-integrals still were invariants. Later I constructed a new proof with the aid of the transformation to action and angular variables, as used by Schwarzschild, and treated in Whittaker's "Analytical Dynamics" (this was in 1916-1917).

So much about Ehrenfest. I will now turn to some of my other professors. I must begin to say that with all my admiration for professor Lorentz (an admiration continually strengthened by Ehrenfest), his personal influence was much less. Lorentz had that natural modesty which is afraid to go too deeply into the mind of another person.



JM Burgers study room

He remained much more aloof, and never subjected us to much questioning, nor pushed us to some topic as Ehrenfest could do.

We revered Professor Lorentz, but the distance was too much for the development of the type of friendship we had with Ehrenfest. I came, however, into closer contact with Professor Lorentz during the period January-September 1918, when I was his assistant in Haarlem.

Professor Kamerlingh Onnes was a much more authoritative person. In the year 1914-1915 he still gave a course on the theory of the monocyte, as developed by Maxwell and by Helmholtz in view of a certain analogy with thermodynamical relations. We were with only three students, and once, when the two others had not turned up he gave for me alone a private lesson on his investigations on superconductivity and on the fact that a magnetic field cannot penetrate into the interior of a superconductor. As I was interested in experimental physics, I also followed a course in glass blowing in the cryogenic laboratory, but I did not become an expert. Gradually I came to carry out measurements with electrical resistance thermometers, and from January 1, 1916 - December 31, 1917, I have been an assistant at this laboratory. My main work has been to read the galvanometers and to help other students with electrical temperature determinations. Experiments with liquid helium could not be carried out during the war years, but in 1917 a vapor cryostat came into use, working in the domain between liquid neon and liquid hydrogen.

Kamerlingh Onnes wished to have his assistant completely for his laboratory who should do observations during daytime, work them out in the evening and write them up during the weekend and one should not flirt with theoretical studies, for experimental physics required the whole person. To this regime I could not subject myself. I was too much interested in theoretical problems and was too much attracted by Ehrenfest. As my mind was not very inventive, I could not arrive at a program for experimental research. Gradually Kamerlingh Onnes noticed that I had strong attachments on the theoretical side; Ehrenfest talked with him about me, and finally Onnes asked me about my plans. I told him that I felt too much attracted to theoretical studies, and I know that it was a great disappointment to him. He has taken it nobly and did not detract his friendship from me. I may mention in passing, that later on, when I accepted the position for fluid dynamics in Delft, Kamerlingh Onnes said that if ever I should like to do experiments on the viscosity of liquid helium he would be glad to have me come back to him. Unfortunately, at that time I looked upon viscosity only as a datum to be used in the calculation of the Reynolds number for a flow pattern, and thought that to measure the viscosity of helium would be just to add another number to a table of physical constants. From what has been found later, it may be that I have missed a great opportunity.

From my professor of mathematics, it was Kluyver from whom I received most, through his excellent lectures on the theory of functions. I remember with great admiration his course on the Riemann function, about which we read at the same time

in the books we found in the "Reading Room". With van der Woude, who gave geometry and analytical mechanics, I have become much befriended, but I did not follow his lectures; he came a year or so later, and I had already studied much of these topics. It was the astronomer W de Sitter, who was an expert in Hamiltonian dynamics, that Ehrenfest took me when I had got the proof for the invariance of the phase integrals, to discuss the details.

I did the 'candidaatsexamen' May 22, 1915. It was Ehrenfest who had prompted me to do it within a year since I had already much preparation before I came to Leiden. The 'doctoraal examen' followed December 1, 1917.

In October 1917 my brother had also come to Leiden to study chemistry. For some months we lived together with the same family where I had been since my arrival. My brother also became a member of Christiaan Huygens, which had more chemists among its members. But with January 1918 I left Leiden for Haarlem, as Professor Lorentz had asked me to accept the position of conservator of the Physical Laboratory of Teylers Stichting, of which laboratory he was the director. My brother remained in Leiden until the summer of 1919, when Professor HJ Backer asked him to become his assistant for organic chemistry at the University of Groningen. My brother's work there was interrupted by a stay of 2 years (1920-1921) in Rome as teacher of the sons of the Netherlands Ambassador for the mathematical and physical subjects. The present Ambassador of the Netherlands in the United States, his Excellency Mr J.E. van Royen, thus has been a pupil of my brother.

After having returned to Groningen, my brother in 1923 received a fellowship from the International Education Board to work on crystal structures at the Royal Institution in London under WH Bragg. This was followed in 1925 by a Ramsay memorial fellowship, and my brother continued to work at the Royal Institution until the summer of 1927, when he was offered a position at the Physical Laboratory of the Philips Factories in Eindhoven. In 1940 he was appointed professor of physical chemistry at the Technical University of Delft. Father has still seen that the two of us were professors at the same University.

To come back to Teylers Foundation this was an institution dating from the end of the 18th century, when everywhere there has been a great interest in the physical and natural sciences. Among its early professors had been van Marum, who constructed a powerful electrical machine with which he performed many experiments. The Foundation also had a museum with rich collections of paintings and drawings; and a collection of physical instruments (among them van Marum's machine); minerals and fossils with a large slab containing the famous reptile 'Andreas Scheuchzer', which Scheuchzer had held to be a remnant of a man who had died with the Biblical Great Flood.

To work at the physical laboratory of this Foundation was a very honorable position. Two of my predecessors, Dr. GJ Elias, and Dr. WJ de Haas, (Lorentz' son-in-law) had carried out important experimental work at the laboratory.

One after the other they had been appointed professor in Delft, Elias for electricity and Maxwell's theory; de Haas for physics. The daily contact with Lorentz was of great value, but nevertheless I felt somewhat lost in Haarlem, though I came weekly to Leiden, with Lorentz on the occasion of his lectures. Now that I was on my own, I suffered from some inability to develop a full program of work for myself

Before I really came to consider this matter seriously within myself, I received an invitation to accept a newly created chair at the Technical University in Delft for aero- and hydrodynamics, in the Department of Mechanical Engineering and Shipbuilding. The jump away from physics and from atomic problems was a large one, but there was also an attractiveness in the idea of starting a new line of work

Hydrodynamics was not treated as a part of classical mechanics in Leiden. Ehrenfest had not much feeling for a domain of science which was governed by non-linear equations, although in 1917 he had directed our attention to a little book by R Grammel "Die hydrodynamischen Grundlagen des Fluges" (The Hydrodynamical Foundations of Flight), in which the theory of the two dimensional circulatory flow around wing profiles was explained. This indicated an interesting field for the application of conformal transformation. In the "Reading Room" I had sometimes looked at FW Lanchesters "Aerodynamic Theory", but this made the impression of an incomprehensible phantasy. Hydrodynamics, as a part of theoretical physics, had a scientific ancestry of high standing, and the names of Lord Kelvin and Helmholtz are connected with many of its intriguing aspects. Even Professor Lorentz had written two important hydrodynamical papers, one on problems of viscous flow which have provided a basis for CW Oseen's theoretical investigations; and one on turbulence, explaining Reynolds' ideas and adding to them some very inspiring developments.

The invitation from the Technical University was made by two professors of the Department mentioned, professor CB Biezeno, who gave the theory of elasticity and lectured on strength of construction; and professor CP Holst, who gave construction of machinery, and who had a great interest and admiration, and I may say, a fine feeling for theoretical work. They explained to me that what they desired was a scientific attitude towards the subject. Although it was the time when flying and airplanes attracted more and more attention, it was not their idea that I should be an expert in flight as a technical achievement: I should have to bring the basic ideas necessary for understanding and mastering the phenomena of flow, and to work in this domain as a scientist. From the discussions it appeared that to cooperate with them, in particular with Biezeno, was very attractive and would protect me from being immersed in technical and industrial relations. In that period the mathematical methods used in hydrodynamics were still closely related to those applied in the theory of elasticity. The cooperation with Biezeno soon developed into a close friendship, and many are the discussions we have had together, not only on matters of scientific interest, but also on problems connected with the welfare of the Technical University, and on personal matters.

I had, of course, to learn hydrodynamics myself and I started to read various papers on vortex motion, among them Ahlborn's photographic work on vortex motion behind bodies which were towed through a large tank with water. I had still to finish my thesis work on "Het atoommodel van Rutherford-Bohr" (The Model of the Atom according to Rutherford and Bohr). It originally had been a prize essay for Teyler's Stichting, which I had written in 1917. HA Kramers had gone to Copenhagen, to work at Niels Bohr's Institute, in the second half of 1916 or the beginning of 1917, and he had not been aware that this theme had been set; otherwise he probably also would have written an essay. The point of view which I had taken had grown out of the work on adiabatic invariants and was based upon a treatment of the equations of analytical dynamics with the aid of contact transformations, as indicated in ET Whittaker's Analytical Dynamics. Professor Ehrenfest was my promotor, and the degree was awarded on November 7, 1918.

The appointment in Delft officially had started October 1, 1918, on which day I had also moved to Delft. On December 2, 1918, I gave my opening discourse with a lecture on "The Hydrodynamic Pressure".

After that I felt myself obliged to abandon the theoretical physics of atomic structure completely. Hydrodynamics needed all attention and it was not possible to serve two masters at the same time. Only after 1926 I made myself acquainted again with the new views on quantum theory, which had developed from the work by Born and Heisenberg and by Schrödinger.

As regard hydrodynamics, the theory of the circulatory flow around airfoil profiles required first attention. Soon we received information concerning Prandtl's work and that of his pupils Max Münk and Albert Betz on the vortex system behind airfoils of finite span. Also Prandtl's boundary layer theory, first presented in 1904 and later worked out by Blasius (1908) and Hiemenz, had to be studied, as well as Osborne Reynolds fundamental work on turbulence. The discussion of this work by Lorentz, who had also extended Reynolds stability calculation, was extremely stimulating. A remark by one of my mathematical colleagues happened to make me acquainted with the work of Oseen - great application was needed to get into the meaning of his calculations. But in 1920 I began to see a relation between certain aspects of Oseen's work and Prandtl's boundary layer theory, and I constructed an intermediate picture by making use of a transformation of the equations for twodimensional flow, given by Bousinesq. It is convenient however, to stop at this point, since many new developments started with the year 1921, when I became acquainted with Dr. T. von Karman.