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**Paul Dirac and Igor Tamm
Correspondence
Part 1: 1928 – 1933**

Commented by
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Abstract

These letters between two famous theoretical physicists and Nobel prize winners, Paul Dirac (1902 – 1984) of Britain and Igor Tamm (1895 – 1971) of the Soviet Union, contain important information on the development of the relativistic theory of electrons and positrons and on the beginnings of nuclear physics, as well as on the life of physicists in Europe and the Soviet Union during 1930s.



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1. Introduction to the Publication

Brief Description

This paper publishes the correspondence between two famous theoretical physicists of this century. Paul Adrien Maurice Dirac is known as one of the key creators of quantum mechanics and quantum electrodynamics, the author of Dirac equation and of *The Principles of Quantum Mechanics*. To lay audiences Dirac is usually presented as the one who predicted anti-matter, or, more precisely, the first anti-particle – the positron. In 1933 he shared the Nobel prize with Erwin Schrödinger “for the discovery of new productive forms of atomic theory”. Igor Evgen’evich Tamm worked on both particle theory and solid state theory, but received his Nobel prize in 1958 for the theoretical explanation of a non-quantum effect – Cherenkov radiation. He shared the prize with experimentalist Pavel Cherenkov and fellow theoretician Il’ya Frank. Tamm was also the teacher of Andrei Sakharov; they worked together on the Soviet H-bomb.

Tamm and Dirac first became acquainted in 1928 when both visited Leiden. Since then they met almost every year till 1937, mostly during Dirac’s trips to the Soviet Union.¹ Their correspondence reflects the important and dramatic things happening in physics during that decade — Dirac’s work on relativistic electron and the hole theory, the development of his ideas leading to the prediction of anti-electron in 1931, the changes in physics caused by the discoveries of the neutron and positron in 1932, and Tamm’s work on the theory of nuclear forces that would eventually help Hideki Yukawa to introduce the meson in 1935.

It is always good for the historian when friends and colleagues have lived far apart from each other and corresponded a lot. Dirac’s proverbial introvertism, non-communicability and restraint from developing closer contacts with people did not show up in his relations with Tamm.² Indeed, it seems that he never had so close a friend in Cambridge, with one possible exception – Piotr Kapitza. Dirac also did not leave

¹Dirac came eight times to the USSR during this decade, every year except 1931 and 1934. Tamm visited him in Cambridge in 1931. Later, Dirac was in the Soviet Union again in 1956, 1965 and 1973.

²“...Once we were walking in Cambridge and talking in a very lively manner. Later one physicist there came to me and said that he had watched us and could not get rid of his amazement, for he had witnessed a non-trivial picture, ‘Conversing Dirac’! ” (one of Tamm’s stories as told by D.S.Danin) [Tamm 1986, s. 143].

many draft manuscripts and letters; the correspondence published here is probably the richest one he ever had with a single physicist and provides us with a unique possibility to look into the background of Dirac's published works.

In striking contrast to Dirac, Tamm was an extravert and very sociable. These features contributed greatly to his important role in the establishment of the Soviet community of theoretical physicists, but, as they were displayed almost exclusively through verbal communications, they have not been recorded well by written documents. We can get some feeling of them, however, from Tamm's correspondence with Dirac. The roles in this friendship were distributed quite clearly. In scientific matters, Tamm followed Dirac's leadership very openly, and Dirac's influence is easily seen in a number of Tamm's publications.³ But he played the leader's role in what regarded social life and personal relations. He introduced Dirac to his hobbies like mountaineering and tree climbing, taught him how to ride a bicycle, etc. Whether he also had an influence on Dirac's political views, I am not sure, but at least they were also close politically during that decade, sharing socialist sympathies. Tamm's letters often touch on wider topics outside physics as such, and they contain valuable information on the social life of Soviet science.

Their friendship and contacts were interrupted almost certainly by the worsening political situation of late 1930s. In 1938 Dirac was not allowed to enter the USSR, as that country and the United Kingdom mutually ceased issuing visas. In the Soviet Union, strict isolationism was replacing the policy of relatively more open international contacts. Corresponding with foreigners not only became difficult, because letters were not coming through, but also very dangerous in the time of the Great Purges. Tamm must be praised for not having destroyed letters from his foreign correspondents in a time when the probability of his arrest was quite real.⁴ Only after the end of the World War II and Stalin's death could Dirac and Tamm again meet and write each other, but they were no longer as close as they had been during the 1930s.

³[Tamm 1930b, Tamm 1930c, Tamm 1930d, Tamm 1931d, Tamm 1934c].

⁴Although the purges functioned at random, convicts among close relatives or colleagues increased the danger of being arrested. Boris Hessen, Tamm's best friend and superior at the Moscow University, was arrested as a Trozkite in 1936. Tamm's brother, Leonid, appeared as a witness at one the famous Moscow trials of 1937. Both became victims of the purges.

Editorial Notes

Altogether, 56 letters between 1928 and 1936 have been preserved with apparently only a few letters lost. They will be all published here (in two parts), including those which seem to be unimportant for physics. The volume did not grow much larger because of this, and I also hope that relevance to physics is not the only criterion why a historian may be interested in reading these documents. Even on a very superficial level, they contain fine details on the life of scientists in Europe and the USSR. To mention only one, I found it interesting that letters between Cambridge and Moscow travelled in the 1930s within five to seven days — an ironical fact for those who have some experience in corresponding with Russia in more recent times.

With the exception of two letters in German, all the rest are written in English. Tamm's writing was not perfect, of course, but I am not a native English-speaker either, and decided to correct only the most trivial mistakes, like spelling. Correct or more conventional versions of names of places and persons are provided in comments. A universally recognized system of transliterating words from the Cyrillic into the Latin alphabet does not exist. For some well-known Russian names tradition exists, and I have usually respected it. For other words and names, the following sequence was used as the representation of the Russian alphabet:

a b v g d e j z i y k l m n o p r s t u f x c ch sh xh " w ' eh yu ya

The formal organization of the publication owes much to the example set by the edition of Wolfgang Pauli's correspondence [Pauli 1979, 1985, 1993]. The following conventions are used:

- < ... > - crossed out in the manuscript;
- { . . . } - text which is impossible to read with confidence;
- [. . .] - editorial extrapolations.

Bibliographical references to Dirac's and Tamm's publications follow the numbering of bibliographies in [Kragh 1990] and [Tamm 1991].

Originals, Earlier Publications and Acknowledgements

The originals of Dirac's letters are in the possession of Tamm's family in Moscow. Tamm's letters were once held in Churchill College in Cambridge, but were recently transferred together with all Dirac's papers to Florida State University at Tallahassee.

I first came across Dirac's letters to Tamm in Autumn 1987 after having contacted Leonid Igorevich Verexhinskiy, Tamm's grandson, while organizing a conference on Paul Dirac. This Moscow conference presented to public the existence of large pieces of Dirac's correspondence with Piotr Kapitza, Igor Tamm, and Vladimir Fock.⁵ By the same time Viktor Yakovlevich Frenkel had received from Cambridge copies of letters of Soviet physicists to Dirac. We prepared to publication the first half of Dirac-Tamm correspondence [Dirac-Tamm 1988], where letters appeared in original language, while the comments I wrote then in Russian. Selected letters appeared in Russian translation in [Dirac-Tamm 1990c].

Recently Manuel G. Doncel of the Universitat Autònoma de Barcelona revived my interest in these documents by suggesting the publication of a volume of Dirac's correspondence with Soviet physicists. The present paper should be considered as a contribution to this future volume. I am grateful to Manuel Doncel and Llorenç Porquer for preparing the computer version of the letters. I partly translated comments from the earlier Russian publication, partly revised them and partly wrote for the first time. I would like to thank Dmitriy Bayuk, Cathryn Carson, Helmut Rechenberg, Karl von Meyenn and Xavier Roqué for comments on the manuscript.

⁵See [Kojevnikov 1988] for the review of the conference.

2. Introduction to the Story

Dirac

Paul Adrien Maurice Dirac was born on 8 August 1902 in Bristol, where his father, Swiss-born Charles Dirac, taught French at a college. Paul graduated in 1921 from Bristol University as electrical engineer, but did not manage to find a job. He proceeded then with the study of mathematics, first in Bristol and beginning in 1923 in Cambridge. There he came under the supervision of Ralph Fowler, one of the few British experts in quantum theory. Fowler had contacts with Niels Bohr and the Copenhagen circle; in August 1925 he received from Werner Heisenberg the proof-sheets of a new paper [Heisenberg 1925], which contained the first sketch of quantum mechanics. Proof-sheets in those days were printed in several copies and circulated fulfilling the role of modern preprints. Fowler passed them to Dirac for study, which is how Dirac entered the field which would make him famous.

His strong appearance came as a surprise to the German-speaking leaders of the new theory, who formed the centre of the small quantum community. Working almost alone on the development of Heisenberg's ideas, Dirac first worked out the so-called theory of q -numbers, which was essentially equivalent to but somewhat more general than Born-Heisenberg-Jordan's matrix mechanics [Dirac 1925d]. The following year, after the appearance of Schrödinger's wave mechanics, Dirac did the work of developing it into the first complete formalism of quantum mechanics [Dirac 1926e, Dirac 1927a], which again paralleled the results of several separate publications of Heisenberg, Born and Jordan. At this time Dirac made personal acquaintance with German colleagues while visiting Copenhagen and Göttingen, the main centres of the new theory. He then proceeded immediately with the relativistic quantum theory, introducing, as the first step towards quantum electrodynamics, the quantum theory of radiation [Dirac 1927b]. In January 1928 he came out with what was probably his most important contribution [Dirac 1928a], which contained the relativistic wave equation for the electron — the Dirac equation. This paper brought to its maximum Dirac's influence on the small community of theoretical physicists who worked on fundamental problems — for more than a year they did nothing else but study various aspects of Dirac electron. At this point, in April 1928, Dirac met Tamm in Leiden, and their friendship began. ⁶

⁶More on the biography of Dirac and his contribution to quantum mechanics can be found in [Kragh 1990, Dalitz-Peierls 1986, Mehra-Rechenberg 1982, Darrigol 1992].

Tamm

Up to the time of his meeting with Dirac, Igor' Evgen'evich Tamm had not yet made a serious contribution to physics, but already had a much larger experience with real life. Born on 3 July 1895 in Vladivostok, on the eastern edge of the Russian Empire, to the family of a railway engineer, Tamm grew up in a Elisavetgrad, provincial town in the Ukraine, and there got interested in politics and in marxism. This was one of the reasons why his parents sent him away from Russia to study mathematics at the University of Edinburgh. After one year, these studies were interrupted by the outbreak of World War I. Tamm came to Moscow University, where his interests shifted from mathematics to physics. Despite some time taken by military service and active involvement in the chaotic politics of the Russian revolution, Tamm managed to graduate in autumn 1918. He spent the years of the revolution and the Civil War quite adventurously, appearing, for instance, in June 1917 in St.Petersburg at the first All-Russian Congress of Soviets as a representative of the Men'shevik party (Social Democrats, rivals of the Bolsheviks), in 1919 as a member of a local Soviet in his home town Elisavetgrad, in 1920 as a physics assistant at Tavria University in the White-Army stronghold Crimea. Several times he slipped across the front lines and several times was arrested by all possible political regimes. Survival was a matter of luck and chance.

This odyssey ended in November 1920 in Odessa. There Tamm got married to Nadejda Vasil'evna Shuyskaya and met his true teacher in physics, Leonid Isaakovich Mandelstam. Mandelstam worked mainly in radiophysics and optics, but also followed the most modern developments in quantum physics. In 1922 Mandelstam and a group of pupils and collaborators moved to Moscow, but it was only in 1925 that he got a good position as professor of theoretical physics at Moscow State University. Tamm had been teaching at the same university since 1924 as something like a Privatdozent; he started working on quantum theory and was indeed the first Russian to publish a paper on the new quantum mechanics (the matrix mechanics of Born-Heisenberg-Jordan) [Tamm 1926d]. Tamm's talk on quantum statistics at the 4th Congress of Russian physicists in Moscow in 1924 attracted the attention of Paul Ehrenfest, who then came as the first foreign physicist to visit Russia after several years of war and revolution.

Ehrenfest was married to a Russian woman and had lived in Russia in 1907 –

1912 before he got a position in Holland at the University of Leiden. He always tried to maintain contacts with Russian physicists despite all the political difficulties and played a very important role in the emergence of theoretical physics in the Soviet Union. With his help, Yakov Frenkel and Yuriy Krutkov received Rockefeller Fellowships and traveled to Europe in 1925. The next year Ehrenfest proposed another pair, Vladimir Fock and Igor Tamm. This time only one of his proteges – Fock – got approval from Rockefeller officials. In order to repair their ‘mistake’, Ehrenfest got a fellowship from the Dutch Lorentz Foundation to bring Tamm to Leiden in January 1928. ⁷

Leiden, Leipzig and Göttingen, 1928

The story of Tamm’s acquaintance with Dirac is presented below by excerpts from documents, in my translation from Russian. If other source is not indicated, is is Tamms’s letter to his wife. The first encounter was indirect — Tamm reviewed Dirac’s recent paper on relativistic electron [Dirac 1928a] at Ehrenfest’s seminar:

“I am very excited – yesterday I reviewed Dirac’s paper for Kramers, Ehrenfest, Fokker and Kronig, and Ehrenfest was satisfied. At least, I did not disgrace myself. ... Ehrenfest does not want to let me go from Leiden until June” (Leiden, 8 March 1928).

“I am totally delighted with Dirac’s latest paper on electron spin. Tamm explained it to us very well. He continues to work on this further. To Tamm’s joy, Dirac is going to spend May and June in Leiden. The Lorentz Foundation has invited Tamm to prolong his stay in Leiden at least through this period” (Ehrenfest to A.F.Joffe, 13 April 1928) [Frenkel 1986a].

“Finally, it became certain that Dirac will come for three months on April 23 ⁸. — I shall learn from the most brilliant representative of the young physics. However, people say that Dirac is a great silencer, that it costs tremendous effort to get a word from him, and that he talks only to children under ten” (Leiden, 4 March 1928).

“Ehrenfest asked his assistants to meet Dirac at the railway station. Igor’ Evgen’evich joined them. Nobody knew what Dirac looked like. Therefore, everyone held

⁷More on Tamm’s biography in [Tamm 1986, Frenkel-Bolotovskiy 1991]. On Ehrenfest and Rockefeller fellowships in [Frenkel-Josephson 1990, Kojevnikov 1993].

⁸Dirac arrived in Leiden from Copenhagen on 27 April 1928

a reprint of Dirac's latest paper on the relativistic electron ⁹ ... and took their places near the doors of every car along the platform. Dirac was fished out with the help of his reprint — Ehrenfest had calculated it well." (One of Tamm's legendary stories, as told by V.Ya.Frenkel) [Frenkel 1986a].

"In the last time I have something like a hang-over — my last paper, at which I had sat for more than a month, is bad.... I also have doubts concerning the earlier papers I have done here. Thus, almost nothing positive has come out of my stay here. Of course, I learned a lot, but I could have done more. I feel like an idiot. One of the reasons for this is that my criteria are rising — Ehrenfest's criterion is no longer high enough (this does not mean, of course, that I have beaten it), the new criterion is Dirac, and I feel like a little child next to him. Of course, it is much more stupid to compare yourself with a true genius"

"Dirac teaches me with great patience; we made a good friendship, which I am very proud of... I just happened to learn that Dirac is invited to a small physical conference in Leipzig on 17 June. Ehrenfest leaves in the beginning of June, so I will travel to Germany together with Dirac" (Leiden, no date).

"Dirac and I became such friends, that he declared: I will travel with Tamm from one town to another until he leaves Germany, and then return to Leiden" (Leiden, 10 June 1928).

"We were travelling by train, second class and express. Another train would have been too inconvenient, and our train did not have third class cars. I was playing chess with Dirac all the way through, we drew a chess table on a sheet of paper, put crosses instead of figures and erased them with a rubber after every move. The trip took 13 hours" (Leipzig, 18 June 1928).

The conference in Leipzig on 18–23 June 1928 was the first in the series of annual 'Leipziger Vorträge' organized by Peter Debye and Werner Heisenberg. Although the topic of 1928 meeting was announced as 'Quantum Theory and Chemistry', the invited speakers lectured on more fundamental problems of quantum theory. Dirac gave a talk on his relativistic electron [Dirac 1928c].

"I arrived in Göttingen yesterday... The Leipzig talks were very interesting, but aside of talks I did not have many contacts with physicists — the famous scientists

⁹I doubt that there were so many reprints in Leiden at the moment – AK.

here did not accept me, an unknown, into their company. A whole bunch of celebrities came here, all so very young. I already knew that all the present stars in physics are very young, but was astonished to see this with my own eyes” (Göttingen, 24 June 1928).

“I plan to leave for Munich on Sunday, the 29th. I shall stay there two and a half days, then meeting Bell ¹⁰ in the Bavarian Alps on the 1st... I hope to make a stop in Nuremberg for a day on my way back, arrive in Berlin on the 8th, and in Moscow approximately on the 13th.”

“In these last days of my stay in Göttingen, there came the feverish thirst for work, and I try to make up for the last two months, during which I worked so little and so badly ... I want also to use these last days for talks with Dirac, with whom I shall soon part after three months of living together, and whom I did not ‘use’ at all for physical questions during the last time, although in Göttingen we were even more inseparable than in Leiden – one could take us for Ajax brothers” (Göttingen, 26 July 1928).

“During my stay abroad I lived five months in Holland and two months in Germany. The best hopes never come true – this is probably a law of nature — nevertheless, I am very satisfied, especially with the first half of my stay when my work went on very well. The last two months I was mainly travelling to the conferences and simply ‘sight-seeing’, climbing the Bavarian ‘Alps’, hiking in the Harz, walking in Nuremberg, Munich, Hamburg etc. What makes me especially happy is that I made a close acquaintance and spent three months with a true genius, Dirac. Don’t smile at the grandiloquent word – it corresponds perfectly to the reality, and I am sure that in my older age I will be proud to tell my grandsons about this acquaintance... I was late for our Russian congress” (Tamm to V.I.Yakovleva, Moscow, 4 October 1928).

Here Tamm mentioned the 6th Congress of Russian Physicists (5 – 16 August 1928). Having parted with Tamm in Göttingen, Dirac came to his first visit to the Soviet Union to attend this congress. In the first letter to Tamm, Dirac told about his impressions of this trip.

¹⁰James H. Bell, chemical engineer, Tamm’s Scottish friend from the University of Edinburgh and his companion on several mountain expeditions.

[1] DIRAC TO TAMM

4-10-28

St. John's College
Cambridge

Dear Tamm,

I am now back in Cambridge after being away six months. ¹ I had a very enjoyable time in Russia. I first spent two days in Leningrad with Born and Pohl ² and we saw the sights and visited the Hermitage and the museum of Russian art and the Natural History Museum ³ and also the Röntgen Institute (I have forgotten its complete name). ⁴ I found Leningrad a very beautiful place, and was more impressed by it than by any other town during the journey, particularly as I come up the river in the steamer and first saw the large number of churches, with their gilded domes, quite different from anything I had previously seen. I can also remember very well some of the Russian pictures, and I was very glad to have an opportunity of seeing the preserved mammoth that one read so much about in the newspapers when it was discovered. ⁵ We climbed to the top of the church of the St. Isaac ⁶ and had a good view of the city from there. The enormous granite columns of this church were very striking.

When we arrived in Moscow the congress was nearly ended. ⁷ According to the program I should have given a lecture there the afternoon after arriving, but I did not hear about it in time, and instead I visited the palace of prince (whose name I have forgotten) which lies a little outside Moscow. That evening I went to the Japanese theater, and the next morning the whole congress visited the Kremlin. In the afternoon I then took a long walk through the streets of Moscow and very nearly lost myself, but managed to get back before dark. I was hoping you might arrive there earlier than you said you would. ⁸ We left Moscow on the evening of August 9th and took up our quarters on the Volga steamer the next morning.

The Volga trip was very delightful and lasted just a week. There were some lectures on the ship; Landau gave one on half-vectors, ⁹ and I gave one myself on the theory of the electron. ¹⁰ We went as far as Stalingrad in the boat, stopping on the way at Kasan and Saratov and at some smaller towns, and once at a place where there was no town at all simply for us to bathe. I carried out your instructions of bathing in the Volga. We had mostly fine weather, but at Saratov it rained the whole day, a very rare event

for that district. I learnt to eat water-melons on the Volga boat and liked them very much. I had never seen any previously. (I should have said before that caviar was the first thing I had to eat on arriving in Leningrad.)

The weather in the Caucasus was perfect. ¹¹ There was a fresh fall of snow the night we arrived at Vladikavkas, so that next morning the mountain tops around were all white. I took part in the excursion to see the glacier, and reached a height of about 3000 m, a good deal higher than my previous record, Brocken. ¹² This excursion took 6 hours, so we had to spend the night at the village near Kasbek. ¹³ The next morning we stopped at the 'Narsan' spring, ¹⁴ and while crossing a stream near here I slipped on a stepping stone and fell in the water, but no ill consequences came from this incident. I spent three days in Tiflis, mostly resting and making up for lost sleep, and then went to Batoum ¹⁵ to try to get a boat for Constantinople. Prof. Darwin ¹⁶ and his wife also wanted to go to Constantinople, and when, on arriving in Batoum, we heard that there was a ship leaving for Constantinople that evening, and that there would not be another for some weeks, we thought we were very lucky. This opinion was changed, however, when we found that we could not get Turkish visas, because it was a Friday (which is the Mahomedan Sunday) and the Turkish consulate was closed, and although Joffé ¹⁷ very kindly brought the governor of the province to help us, he could not do anything. We heard that evening that the ships papers were not in order, and could not be put in order for some reason that the Turkish consulate was closed. Thus the ship had to wait till the next day, and we were able to get our visas and travel by it. Before leaving Batoum I had a chance to bathe in the Black Sea, and also visited the botanic gardens, where I was very interested to see so many tropical trees.

From Constantinople I took a ship to Marseilles, visiting Athens and Naples on the way, and then came home across France and ended a most pleasant holiday.

I have been invited by Joffé to Leningrad next spring and have not yet decided to go or not. I should be very glad to know whether you will then be in Leningrad or Moscow, as this may affect my decision. I should be very glad to meet you again if possible. ¹⁸

With best wishes from

P.A.M. Dirac

¹ Dirac's itinerary can be approximately reconstructed from available letters as follows: Copenhagen (April 1928) — Leiden (27 April – mid June) — Leipzig (Leipzige Woche, 17 – 23 June) — Göttingen (23 June – end of July) — Leningrad (5 or 6 – 7 August) — Moscow (8 – 9 August) — Volga trip (10 – 16 August) — Caucasus trip (17 – 25 August) — Mediterranean trip (September 1928).

² Max Born (1882 – 1970) and Robert Wichard Pohl (1884 – 1976) — physics professors from Göttingen University.

³ Museums in Leningrad: Hermitage, Russian Museum, Kunstkamera.

⁴ Commonly known as Leningrad Physico-Technical Institute, it had at the time of Dirac's visit the official name State Physico-Technical and Roentgenological Institute (*Gosudarstvennyy fiziko-texnicheskiy rentgenologicheskiy institut*) and was the largest physical institute in the Soviet Union.

⁵ The frozen body of a mammoth was found in Siberia in 1920s and brought to Leningrad.

⁶ The city's main cathedral.

⁷ The Russian Association of Physicists was founded in 1919 and held more or less regularly general congresses. The 6th Congress of Russian Physicists (5 – 16 August 1928) had the first part of its sessions in Moscow and continued on board a ship going down the Volga river. The Congress was attended by more than a hundred Soviet and by somewhat twenty foreign physicists (Cz.Bialobrzewski, M.Born, L.Brillouin, C.G.Darwin, P.Debye, P.Dirac, Ph.Frank, G.Lewis, R.von Mises, S.Piénkowski, R.W.Pohl, P.Pringsheim, K.Scheel), and symbolized the short period of intensive international contacts of the maturing Soviet physics. More on the congress in [S"ezd 1928a, S"ezd 1928b, Born 1928, Sominskiy 1964].

⁸ Tamm returned to Moscow from Germany on August 12, two days after the Congress left for the Volga.

⁹ Lev D.Landau (1908 – 1968) was at that time an unknown graduate student at the Leningrad Physico-Technical Institute. Initially, he was supposed to talk on the attempt he made together with Dmitriy Ivanenko at a relativistic quantum theory of spin [Ivanenko-Landau 1928], but while their paper was in print, it was made out-of-date by the Dirac equation [Dirac 1928a], and this could have caused the change in the topic to half-vectors (spinors, basic mathematical elements of Dirac's theory).

¹⁰ According to Ivanenko, Dirac's talk did not deviate significantly from his published papers.

¹¹ After the congress a group of participants made a sightseeing tour in the Caucasus (Stalingrad – Vladikavkaz – Tbilisi – Batumi).

¹² Tamm was one of the first enthusiasts and promoters of alpinism in the Soviet Union, and he had interested Dirac in this sport. Together, they ascended Brocken (1142 m) in the Harz during their stay in Göttingen in July 1928.

¹³ Kazbek (5043 m) – one of the two main summits in the Caucasus.

¹⁴ Narzan – name of a famous mineral water spring. Often used in Russian as a generic name for mineral water.

¹⁵ Tiflis and Batum – old russified names of the Georgian towns Tbilisi and Batumi.

¹⁶ Charles G. Darwin (1887 – 1962) – physics professor at the University of Edinburgh.

¹⁷ Abram F. Joffé (or Ioffe) (1880-1960) – director of the Leningrad Physico-Technical Institute (note 4), president of the Russian Association of Physicists and the chief organizer of the 6th Congress of Russian physicists.

¹⁸ Dirac did not come to Leningrad in spring 1929, because he went on a lecture tour in the USA (letter 4). He met Tamm on his way back home through Siberia and Moscow in October 1929 (letter 10).

[2] TAMM TO DIRAC

8-11-28

Moscou, 6

Skatertny per. 6/2, k. 50

Dear Dirac,

I was very glad to get your letter with such a detailed account of your journey and to find, that you enjoyed it. I hope that the unintentional bath in the icy streams has not spoiled your first impression from real higland, & that you do sympathize now with my mountaineering hobby. But the impressions from the Mediterranean were perhaps not only the last, but also the best ones?

Nein, das Englische ist zu schwer für mich—Sie werden mir schon das Deutsche verzeihen müssen!

Ich fand die Bayerischen Alpen sehr schön, viel schöner als den Harz. ¹ Schroffe, zackige Berge, steile Abhänge, viel Wald und besonders die schönen Seen. Auf die Zugspitze (3000 mtr) ² kletterte ich ganz allein und fand zu meinem Erstaunen, dass auf allen schwierigen Stellen des Weges ein Drahtseil zum Handgreifen aufgespannt war und die in den Felsen befestigten eisernen Stangen eine Art Leiter bildeten! Einmal war es mir unheimlich zu Mut, obwohl absolut kein Gefahr vorhanden war: Punkt um Mitternacht wanderte ich ganz allein durch einen schmalen in den Felsen eingehauten Gang (14 Tunnelle und 2 Brücken), unter den Füßen braust der Strom, zwei Wasserfälle bespritzen mich vom Kopf bis Fuss, durch den Tunnel saust der Wind [und] löscht die Kerzenlanterne aus — brrr.

Einen besonders grossen Eindruck hat auf mich auch Nürnberg gemacht — besuchen Sie [es] unbedingt, wenn Sie das nächste Mal nach Deutschland kommen.

Bitte seien Sie nicht böse, dass ich so lange Ihren Brief nicht beantwortet habe. Wahrscheinlich habe ich Ihnen erzählt, wie schlecht die persönliche Verhältnisse in unserem Institut sind, und das wir mit einer Gruppe von quasi-Physikern zu kämpfen haben, die in dem Institut die Macht besitzen. ³ Fast die ganze Zeit seit meiner Rückkehr nach Moskau und besonders der letzte Monat waren für mich ganz und gar

verdorben durch eine Unzahl von grossen & kleinen Unannehmlichkeiten, Skandalen usw., die jedem die Seelenruhe und Lebensfreude <verdorben> {geraubt} hätten. *

Ich habe die Antwort auf Ihren Brief von Tag zu Tag verschoben in der Hoffnung, dass endlich die Sachlage klar werden wird und {... } auch die Frage, ob wir nach Leningrad übersiedeln oder nicht, endgültig entschieden sein wird. Leider ist es noch immer nicht der Fall — wahrscheinlich bleiben wir aber in Moskau. Jedenfalls werde ich im Frühling sicher noch in Moskau sein. ⁵

Es war mir eine sehr grosse Freude zu erfahren, dass Sie vielleicht im Frühling nach Leningrad kommen werden, und ich hoffe, daß Sie Joffe's Einladung annehmen werden. Falls es der Fall sein wird, werde ich es so einrichten, um während Ihres Aufenthaltes für 7 - 10 Tage nach Leningrad zu kommen — Sie können sich denken, wie hoch ich die Möglichkeit schätze, Ihnen wieder begegnen zu können. Vielleicht wird es Ihnen auch möglich sein aus Leningrad für einige Tage nach Moskau zu kommen — Sie haben doch so wenig hier gesehen.

Ich habe jetzt 14 Stunden Vorlesungen pro Woche und gestern habe ich den einzigen "course of lectures" angefangen, der mir wirklich angenehm ist — "Über Dirac's Quantenmechanik".

Hoping to meet you in Leningrad,

yours sincerely

Ig[or] Tamm

* Und dazu noch die Wohnungsfrage — seit mehr als zwei Monaten habe ich mich zum Überziehen in eine andere Wohnung bereitgemacht, habe viele Sorgen damit gehabt, bleibe aber noch immer in dem alten Zimmer (a family of 5 in one single room!) und vielleicht werde [ich] noch bis zum Sommer hier leben müssen. ⁴

¹ Having ascended Brocken in the Harz together with Dirac, Tamm travelled from Göttingen to München and, before returning to Moscow, spent first days of August in the Bavarian Alps with his Scottish friend James H. Bell.

² Zugspitze (2963 m) – the highest summit in Germany.

³ Tamm had a position comparable to Privatdozent at Moscow State University and another as a research fellow at the University's Scientific Research Institute of Physics (Nauchno-issledovatel'skiy institut fiziki). The institute was controlled by the group of Arkadiy K. Timiryazev, who was an outspoken critic of modern physics – relativity and quantum mechanics. Tamm belonged to the group of Leonid I. Mandelstam, a university professor of theoretical physics and a supporter of modern theories.

⁴ Several families sharing one apartment was typical for living conditions in the cities in the period of socialist industrialization. Tamm's family got a separate flat in November 1929 (letter 11).

⁵ Because of conflicts within the Moscow institute, Mandelstam once considered moving with his collaborators to Ioffe's Leningrad Physico-Technical Institute.

[3] TAMM TO DIRAC

27-12-28

Moskau, 69

Skatertny per. 6/2, k.50

Happy New Year!

Being certain that in the coming year your work will be equal to your previous successes, I can wish you only to heat your travelling records especially as it gives me the hope to meet you in the spring in Leningrad. Will you come?

How far are you with your book? ¹

Yours sincerely

Ig[or] Tamm

¹ This is the earliest indication that already in 1928 Dirac had plans to write a book on quantum mechanics. He finished it only in 1930 [Dirac 1930e].

[4] DIRAC TO TAMM

3-1-29

St. John's College
Cambridge

Dear Tamm,

Many thanks for your letter and card. I am very sorry that I shall not be able to come to Leningrad this spring, but I shall be going to America at the end of March. It has been arranged that I shall be in Madison, Wisconsin, during April and May and shall give a course of lectures there, and that I shall be in Ann Arbor, Michigan, for the summer semester at the end of June and during July. I may perhaps then go to Japan and come back across Siberia, in which case I should hope to see you in Moscow some time about the beginning of October. I should very much like to meet you again. ¹

I was glad to hear that you had a good time in the Bavarian Alps while I was doing the same in Russia. I can still remember my visit to Russia very clearly; in particular my walk through Moscow and the trip across the Caucasus. I was rather tired on the way back and did not stop long at any place on the way. I had the opportunity while going through the Mediterranean of playing chess with a former German master of the game.

The book is progressing with a velocity of about 10^{-8} Frenkel. ² I have started writing it again in what I hope is the final form and have written about 90 pages. I shall try hard to finish it before going to America. It is to be translated into German. Have you seen Weyl's book on 'Gruppentheorie und Quantenmechanik'? It is very clearly written and is by far the most connected account of quantum mechanics that has yet appeared, although it is rather mathematical and therefore not very easy. ³

I have had two letters from Rutgers. He is now working at radio-active disintegration on the lines of Gamow, and is still at KOVA. ⁴

With best wishes for the new year

Yours sincerely,

P.A.M. Dirac

I have not forgotten the cycling that I learnt in Leiden, and have already cycled about 2000 km. in the neighbourhood of Cambridge.

¹ Dirac was a visiting professor at the University of Wisconsin in Madison and then lectured in Ann Arbor at the University of Michigan's summer school in physics. More on his American journey and on his return travel via Japan and Siberia see [Kragh 1990, p.71-75],[Brown-Rechenberg 1987], letters 6 and 10.

² Yakov I. Frenkel (1893-1951), a theoretical physicist from the Leningrad Physico-Technical Institute, had published already 10 books on theoretical physics by 1929 and was just finishing his book on wave mechanics [Frenkel 1929].

³ [Weyl 1928], preceded only by popular accounts, became the first serious book on quantum mechanics. It was indeed, very difficult to read, and even Dirac, in an interview to American journalist, mentioned Weyl as the scientist he could not understand [Kragh 1990, p. 72-73].

⁴ A.J.Rutgers, Dutch physicist, was working on his doctor thesis with Paul Ehrenfest in Leiden in 1928, where he met Tamm and Dirac. Georgiy (George) A. Gamov (1904-1968) – Soviet, after 1934 American, physicist. In 1928, with a theory of α -decay [Gamow 1928], initiated the application of quantum mechanics to the atomic nucleus. KOVA - ?

[5] TAMM TO DIRAC

20-3-29

Skatertny per. 6/2, k. 50

Moskau, 69

Dear Dirac,

Many thanks for your letter and "die Separatabdrücke". ¹ I am enclosing a copy of my note shortly to appear in *C[omptes] R[endus]*. I hope the propositions set forth in the note shall prove to be right, although I am accustomed to find, that <most of> my splendid hopes are only most deflorable [deplorable ?] illusions. ²

Since I finished the proofs of my loathed book ³ in December last I began again to work scientifically and the general conditions for research-work in our Institute have been also considerably improved. ⁴ Making use of the interesting papers of G. Thomsen (*Mathem[atische] Z[eit]schr[ift]*, **29**, 96, 1928) I succeeded as it seems to work out the *classical* theory of the rotating electron (the paper is to appear in *Z[eitschrift] f. Ph[ysik]*). ⁵

During this winter I have had no opportunity of ski-going, but every Sunday I played volley-ball in the open and find it a most interesting game. There was only one Sunday in January when a severe cold (-35° C) prevented us to play the game.

I think, that you are already sailing * to the coasts of America & that this letter will reach you only in Madison. I am sure you will enjoy very much the journey in America & Japan and become an accomplished globe-trotter, you happy man! You will probably meet in Madison Prof. Frumkin, a friend of mine whom I told you about occasionally in Leipzig, a very nice chap & a clever man. ⁶ Please give my best regards & greetings to him & to his wife.

I am expecting very eagerly your visit to Moscow in October next on your way back. Yours sincerely,

Ig[or] Tamm

* Can you really *sail* on a *steamer* ?

¹ Probably reprint of [Dirac 1929a].

² See letter 6, note 1.

³ ‘Loathed’ refers to a large amount of time Tamm had spent on reading the proofs of the book [Tamm 1929a] first in Leiden and then in Moscow.

⁴ See letter 2, note 3. The cause of the improvement may have been Mandelstam’s election to the Soviet Academy of Sciences in January 1929. Later that year, Timiryazev lost most of his power after being defeated in a philosophical dispute by a competing group of marxist philosophers [Joravsky 1961]. Boris Hessen, one of Timiryazev’s philosophical opponents and also a close friend of Tamm, came to direct the Institute of Physics at the Moscow University. He strongly favoured the group of Mandelstam.

⁵ [Tamm 1929e]. ‘Classical’ here means ‘pre-quantum-mechanical’. Tamm started working on this paper with Ehrenfest in Leiden. Following earlier papers [Thomas 1926] and [Frenkel 1926], he wanted to describe the electron spin with the model of relativistic rotating electron. Tamm made use of the equations of motions for an uncharged rigid body in the special theory of relativity derived in [Thomsen 1928]. Although this activity had lost most of its meaning after the appearance of the Dirac electron [Dirac 1928a, Dirac 1928b], Tamm finished his paper in February 1929.

⁶ Aleksandr N.Frumkin (1895-1976) – physical chemist, close to the Mandelstam group. Worked in Moscow in the L.Ya.Karpov Institute of Physical Chemistry. In 1928-1929 lectured in the USA. Later member of the Soviet Academy of Sciences and the director of the Academy’s Institute of Physical Chemistry.

[6] DIRAC TO TAMM

15-4-29

The university of Wisconsin Madison
Department of Physics

Dear Tamm,

Many thanks for your letter and the copy of your note to the *C[omptes] R[endus]*.¹ I was very interested to read this note and have also discussed it with Heisenberg, whom I visited in Chicago a few days ago.² The main idea of this work is a good one, namely that the electromagnetic potentials should not appear in two ways in the theory, once in the wave equation of the electron and once through Einstein's equation

$$\Lambda_{\mu\lambda}^\lambda = a \Phi_\mu,$$

like in Wigner's last paper in the *Zeits[schrift] f. Phys[ik]*,³ but only in the second of these two ways. There is a difficulty in your theory which was pointed out to me by Heisenberg. In the case of no gravitational field your equations do not reduce to those of my theory⁴ and before one could accept your equations one would have to see whether they also give the correct fine-structure formula for hydrogen, which does not at first sight seem very likely. Heisenberg himself has been doing some work on this question of fitting in the quantum theory of the electron with Einstein's new theory, and so also has Weyl (whom I met in Princeton) so you will have a good deal of competition if you go on with this work, but do not be discouraged by it.⁵

I arrived in Madison about two weeks ago, after spending a few days in New York and in Princeton. I shall be staying here till the end of May, giving a course of lectures on Quantum Mechanics, and shall then go to Michigan University at Ann Arbor.

I expect to leave America in the middle of August, which is about the same time as when Heisenberg will leave, so we shall go together to Japan. After that Heisenberg will return through India and I through Siberia.⁶ I expect to leave Japan about Sept. 20th. I should like to know what to do to get a Russian visa, and would be very glad of your assistance in this matter. There is another Englishman at the University here who is thinking he may return via Siberia (at the same time) and would like to know how to get a visa. I should also be glad of any information you may be able to give me about the trains across Siberia, and the relative advantages of going through

Vladivostock or Mukden.

Hoping to meet you in Moscow at the beginning of October,

Yours sincerely,

P.A.M. Dirac

I did not know you could write such good French. ⁷

¹ [Tamm 1929c]. Tamm sent his manuscript to Ehrenfest and asked to arrange the publication. Instead of the *Comptes Rendus hebdomadaire des séances de l'Académie des sciences (Paris)*, as was initially planned, the paper appeared in the *Proceedings* of the *Koninklijke Akademie van Wetenschappen te Amsterdam*, submitted by Ehrenfest.

Tamm's paper is a response to Einstein's new proposal towards a unified theory of electromagnetism and gravity [Einstein 1928a, Einstein 1929a]. Einstein's project attracted attention of many quantum theorists, because mathematical apparatus involved to describe its basic idea of the *Fernparallelismus* seemed to be connected with the spinors in the Dirac theory of relativistic electron (See [Vizgin 1985]). The idea was widely discussed throughout 1929 by many authors including V.A.Fock, D.D.Ivanenko, M.A.Leontovich, M.S.Vallarta, H.Weyl, N.Wiener, and E.Wigner, and later abandoned without having contributed much to the progress of the unified field theory. An important side effect of that activity was a generalization of the Dirac equation for the case of general relativity by Fock and Weyl.

A clip from an unidentified British newspaper of 22 February 1929 with a note "*Einstein's new theory. A hint of its meaning.*" could have drawn Tamm's attention to the topic. An anonymous correspondent there described Einstein's unified 'Universe' and concluded the note writing: "There is still another universe, namely, that which will consistently satisfy quantum phenomena besides gravitation and electro-magnetism. Who will invent that? Dirac, perhaps." Tamm received the clip on 4 March 1929 with a letter from James Bell, who wrote: "I also enclose a cutting concerning Einstein's latest work, from the general press, which might interest you as the name of Dirac seems out of whom great things are expected". Tamm's paper is dated March 14.

² Werner Heisenberg (1901 – 1976), the author of quantum mechanics, in 1927 – 1943 professor at Leipzig University. During the summer semester of 1929 Heisenberg was a visiting professor at the University of Chicago. His lectures there were published as the famous book

The Physical Principles of the Quantum Theory [Heisenberg 1930]. The story of his contacts with Dirac during that visit is told in [Brown-Rechenberg 1987].

³ [Wigner 1929].

⁴ I.e. to the Dirac equation, on the basis of which C.G.Darwin had calculated the formula for the fine structure of the hydrogen spectrum.

⁵ Heisenberg did not come to publish on the topic. Hermann Weyl (1885 – 1955), mathematician, professor at Eidgenössische Technische Hochschule in Zürich, visiting professor at Princeton in 1929. Weyl published three notes [Weyl 1929a, Weyl 1929b, Weyl 1929c] on the translation of Dirac's theory of electron into general relativity.

⁶ See [Brown-Rechenberg 1987] for the story of this trip.

⁷ The manuscript of Tamm's paper is in French, but the published paper is in German [Tamm 1929c].

27-5-29

Dear Dirac,

I am awfully glad you do come to Moscow. I was absent from Moscow for almost a month (part of this time I was at Charkov at the conference of theorists, where you were invited and where I made acquaintance with Jordan),¹ but within a fortnight or so I will collect all the information about visa, best route etc. and write about it to you.

Several persons pointed out to me, that I made a fault not to symmetrise the wave-equation I proposed in the paper, copy of which I sent to you (it appeared not in *C[omptes] R[endus]*, but in *Amsterd[am] Proceed[ings]*).² I find now, that the right form of the equation is

$$(kA^\nu p_\nu + \bar{k}p_\nu A^\nu + mc)\psi = 0,$$

k being a number subject to condition $k + \bar{k} = 1$ (the bar means complex-conjugate). If one puts $k = \frac{1+in}{2}$, then n is proportional to the charge of the particle. The “Eigenwerte” and “Viererstrom” are real.

Yours Ig[or] Tamm

¹ The first Soviet conference on theoretical physics was held in Kharkov on the 19-25 May, 1929. Kharkov was going to be the seat of the Ukrainian Physico-Technical Institute, which was under construction. About fifty Soviet physicists and Pascual Jordan and Walter Heitler from Germany participated in the conference. Vladimir Fock and Dmitriy Ivanenko edited the proceedings, which were published in *Physikalische Zeitschrift*, Jg.**30**, ## 19-20 (1929). Einstein’s new unified theory (letter 6, note 1) was at the centre of discussions. Tamm gave two papers [Tamm-Leontovich 1929g, Tamm 1929h]. For more details see [Obreimov 1973, Kojevnikov 1989].

² Hendrik Casimir was one of those who pointed out the mistake [Tamm 1986, s.297]. The correction was published in [Tamm 1929d] and [Tamm 1929h], where the equations of this letter come from.

[8] TAMM TO DIRAC

28-6-29

Skatertny per. N 6/2, k. 50

Moskau, 69

Dear Dirac,

Excuse me please that I did not answer you for so long a time — I was really very busy with University work and partly with physics.

The usual way to get a <transit> visa is to apply to the General consulate in Tokyo. Citizens of the states with which we are in diplomatic relations get a transit visa immediately, but for those of the states with which we have no diplomatic relations the permission of Moscow has to be asked for. ¹ If you pay at the consulate in Tokyo the telegraphic expenses, the permission will be received within about 5 days. If you got a transit visa with which you can travel to Moscow, it is an easy thing to get here a prolongation of the visa. I {cannot} of course “garantieren” these informations, but I suppose them to be true.

That is the {usual way, but for you} the matter will be of course far easier, especially as you were already in Russia last year. I was told at the Foreign Office that if I apply for a visa for you (which I shall do next Wednesday), the visa will be sent to Tokyo within a week or 10 days. I will ask for a visa for a month “Aufenthalt” in Russia (it can easily be prolonged) and will write to you when it will be ready.

The two ways Japan – Moscow:

1. Jockogama – Tsurugi * (Japan) by railway, then Tsurugi – Vladivostok by boat and the express Vladivostok-Moscow without changing the car 225 hours (Vlad. – Mosc.).

2. Cobe-Fusan (Korea) by boat, then to Andung (Manchjuria), I don't know by which vehicle and then by train Andung – Mukden – Harbin – Moscow about 200 hours. The second way takes less time but the first is cheaper and is said to be more comfortable, because you don't change the car from Vladivostok till Moscow, whereas

¹* I don't know the english spelling of the Japanese & Chinese places which is probably very different from that used by me. ²

going the second route you have to change it 2 or 3 times (the last time at the Russian frontier).³

I am very sorry to say, that in my paper sent to you (it appeared not in *C[omptes] R[endus]* but in *Amsterd[am] Proceed[ings]*) I made the blunder not to symmetrise the wave equation, so that a number of my conclusions was wrong.⁴ In the beginning of June I sent to *C[omptes] R[endus]* a new <second> version of the note. I write now the wave equation in the form

$$(\lambda\alpha^\nu p_\nu + \bar{\lambda}p_\nu\alpha^\nu)\psi + imc\psi = 0,$$

$$\alpha^\nu = {}_s h^\nu \alpha^s;$$

λ being a constant subjected to the condition $\lambda + \bar{\lambda} = 1$ (the bar denotes the complex-conjugate value). If one writes $\lambda = \frac{1+in}{2}$, the constant n can be show to be proportional to the charge of the particle.

I lost a lot of time in calculating the statical solutions of spherical symmetry of the Einstein's field-equations, firstly of the version, published in January, then of that published in April (the paper is sent to *Zeitsch[rift] f. Physik*),⁵ but now I hope to have some time to finish some investigations relating to the energy-impulse *tensor*, which corresponds to the symmetrised wave-equation.⁶

On the 19. of July I leave {...} Moscow for Central Caucasus, where we with my friends hope to make some new ascensions of mountain-peaks still untouched by human feet.

I shall be back in Moscow about the 1st of September and will eagerly await your arrival.

Yours sincerely,

Ig[or] Tamm

Please, excuse the dirtiness of the letter — the cause of it is my bad knowledge of the English language.

¹ Diplomatic relations between the USSR and the United Kingdom were broken from 1927 to November 1929.

² More usual spelling: Yokohama, Tsuruga, Kōbe, Pusan, Antung, Manchuria.

³ The first railway route via Vladivostok went entirely through Soviet territory. The second, via Mukden, went partly through China. The so called Chinese–Oriental railroad was at the moment under the joint jurisdiction of China and the USSR. A military conflict between the two countries disrupted the regular railway operation in the summer and autumn of 1929. Therefore, Dirac took the first route via Vladivostok.

⁴ See letter 7, note 2.

⁵ In April 1929 Einstein published a modified version of his theory [Einstein 1929b]. Tamm speaks of his paper with Mikhail Leontovich [Tamm-Leontovich 1929f]. The authors managed to find a static solution with spherical symmetry only in the case of an uncharged particle. They argue that only solutions with axial symmetry are possible for a charged particle.

⁶ Tamm's added his expression for the energy-momentum tensor to [Tamm 1929h] while correcting the proof sheets of the paper on 9 July 1929.

[9] TAMM TO DIRAC

19-7-29

Dear Dirac,

As I was informed in the Foreign Office, the visa for you was sent on the 16-VII to our Consulate at Tokyo. If you nevertheless will meet with difficulties in Tokyo, what seems to me quite improbable, please wire to me immediately. I am leaving Moscow tomorrow and will be back again from Caucasus about the 1st of September (anyhow not later than the 5th).

Hoping to see you soon in Moscow, Yours sincerely,

Ig[or] Tamm

[10] DIRAC TO TAMM

12-9-29

The Miyako Hotel
Kyoto, Japan

Dear Tamm,

I shall leave Japan for Moscow on Sept. 21st. I shall take the Northern route from Vladivostock, which does not go through China at all, as this is the only way now open.¹ I shall leave Vladivostock in the early morning of Sept. 24th and get to Moscow in the morning of Oct. 3rd at about 8 o'clock. I cannot remember the exact time of my arrival in Moscow and have left my time-table in Tokyo, but as there is now only one train a week from Vladivostock I expect you will be able to find it out without difficulty.

I am afraid I will not be able to stay in Moscow for more than about two days (perhaps till the evening of Oct. 5th) as the term in Cambridge begins soon after. I am looking forward to meeting you again.

Yours sincerely,

P.A.M. Dirac

¹ See letter 8, note 3.

[11] TAMM TO DIRAC

5-2-30

Kiev

Lieber Dirac,

Ich danke Ihnen sehr für den Separat, den ich vor einigen Tagen bei der Durchreise durch Moskau <bekommen> erhalten habe. Pr[ofessor] Ehrenfest, der Ende Dezember in Moskau war, hat mir eine Kopie Ihres Briefes vom 26.XI an Pr[ofessor] Bohr gezeigt, so dass ich die Hauptsache schon kannte. ¹ Die Idee, die ganze Frage nach der negativen Energie auf den Kopf zu stellen und aus der vermutlichen Schwierigkeit eine unitäre Theorie der Elektrizität zu schaffen — wenn man sie einmal erfährt, dann leuchtet sie wie ein Blitz ein! Ich hoffe innigst, dass es Ihnen gelingen wird die Masse des Protons zu berechnen und dadurch Ihre ganze Theorie zu stützen. ²

Die Diskussion der Compton-Streuung, die in Ihrem Briefe an Bohr noch fehlte, hat mich auch ganz besonders interessiert. Ich habe nämlich in der letzten Zeit gerade über der von Ihnen {berührten} Frage gearbeitet. Auch ich habe {gefunden}, dass Zwischenzustände mit negativer Energie bei der Comptonstreuung eine ganz wesentliche Rolle spielen (was die physikalische Bedeutung dieser Zustände beweist) und konnte die in Ihrer Arbeit besprochene diesbezügliche Schwierigkeit nicht beantworten, so dass Ihre Erklärungen mir besonders erwünscht waren. ³ Ich kann nur nicht gut verstehen, wie die übrigens sehr wesentliche Wechselwirkung der Elektronen negativer Energie bei der Berechnung der Übergänge mit einer Zwischenstufe negativer Energie unberücksichtigt bleiben kann. ⁴

Was meine Arbeit betrifft, so habe ich die von Ihnen und von Heisenberg & Pauli gegebene Quantelungsverfahren benutzt (Diracsche Wellengleichung des Elektrons, Quantelung der ψ -Wellen und der Lichtwellen, Dirac-Fermische Statistik der Materie). Ich habe aber mit gewöhnlichen Maxwellgleichungen (ohne das ε -Zusatzglied) gerechnet und $\varphi = \Phi_4 = 0$ gesetzt. ⁵ Weiter habe ich nicht mit stehenden, sondern mit fortschreitenden Licht- und Materie-Wellen gerechnet; um zu erreichen, dass das

Spektrum diskret bleibt, führe ich nach Born die Bedingung des "Zyklischen Gitters",⁶ d.h. die Bedingung der räumlichen Periodizität des Feldes ein. *

Endresultate: die Streuformel unterscheidet sich von der von Klein & Nishina gegebenen in Gliedern nicht nur der zweiten, sondern schon der *ersten Ordnung* in $\alpha = \frac{h\nu}{mc^2}$.⁸ In dem experimentell untersuchten Bereiche der γ -Strahlen (etwa $\lambda = 2 \cdot 10^{-10}$ cm bis $\lambda = 0.5 \cdot 10^{-10}$ cm)⁹ bleibt aber der Unterschied der neuen Streuformel von der Klein-Nishina'schen klein (etwa < 5%), so dass die Übereinstimmung mit dem Experiment gut bleibt. Dieser Unterschied wächst aber mit ν , so dass für die durchdringliche kosmische Strahlung die nach der neuen Formel berechneten Wellenlängen etwa 3 bis $3\frac{1}{2}$ Mal *kleiner* ausfallen, als die nach Klein und Nishina berechneten. (Hat man also vielleicht die kosmische Strahlung mit Bothe als eine *Korpuskular* strahlung zu deuten?)¹⁰

Es muss freilich noch ein Teil meiner Rechnungen kritisch durchgesehen werden; sonst aber bin ich mit ihnen fertig und wollte die Arbeit für den Druck bereiten. Jetzt glaube ich aber aus der Anmerkung in Ihrer Arbeit schliessen zu müssen, dass diese Fragen bereits von Waller erledigt sind. Wenn es so ist, so ist es vielleicht unnötig meine Arbeit zu publizieren?¹¹

Seit November lebe ich endlich in der neuen Wohnung — 3 Zimmer (und Küche) statt einer — und bin glücklich. Meine Adresse ist Gerzen str. 5, k.12 Moskau, U.S.S.R.

Dieses Jahr haben wir unsere Ferien nicht am Weinachten, sondern in der zweiten Hälfte Januars gehabt. Ich fuhr erst zu meinen Bruder in der Nähe von Nischnij,¹² wo ich Ski gelaufen bin und gelernt habe Motorrad (Motocycle) zu fahren. Es ist sehr lustig, anfangs ging es schlimm, dann aber ganz gut, bis endlich mit mir eine Havarie passierte: ein Pferd hat sich plötzlich von dem Motorrad {erschrocken}, und {rutschte} mit den Schlitten seitwärts so weit und unerwartet aus, dass ich an die Schlitten stieß und das Rad beschädigte. Den nächsten Tag ging aber das Radfahren von neuen wieder los.

^{1*} In *Z[eitschrift] f. Ph[ysik]* erscheint demnächst meine Arbeit, in welcher ich Ihre Theorie der Streuung auf die Lichtzerstreuung in festen Körpern erweitert und das gleiche Verfahren benutzt habe.⁷

Ich bin jetzt bei meinen Eltern in Kiev, muss aber morgen nach Moskau zurückfahren.

Wie steht es mit Ihrem Buch? Wenn Sie es noch nicht beendet haben, so werden Sie jetzt wahrscheinlich bei der Ausarbeitung Ihrer neuen Theorie keine Zeit dazu haben. Es ist {doch wirklich wahr}, dass Sie Ihre schönsten Arbeiten immer im Winter machen!

Sie werden mir wohl verzeihen, das ich deutsch und nicht englisch schreibe, was mir doch viel einfacher ist.

Yours sincerely ,

Ig[or] Tamm

Wie war es mit der Luftfahrt von Leningrad nach Berlin gewesen? Und wie fühlt man sich in der Heimat nach einer Weltreise?

¹ [Dirac 1930a], where Dirac proposed his ‘hole theory’, suggesting that the states with negative energy solutions of the Dirac equation are filled with electrons, and that unfilled vacancies are to be identified with protons. Dirac first announced his theory in a letter to Niels Bohr of 26 November 1929. For the text of this letter and detailed discussion of the hole theory see [Moyer 1981b],[Kragh 1990, p. 87-105].

Tamm became one of very few physicists who supported the hole theory. With his introduction, Dirac’s paper was published in Russian translation in *Soviet Physics Uspekhi* [Dirac 1930a’, Tamm 1930a].

² Already in his first presentation of the hole theory [Dirac 1930a], Dirac mentioned as an important difficulty that in the apparently symmetrical theory there was no obvious way to account for great difference in masses of the proton and the electron. His hope to solve this problem was shattered later by Pauli’s and especially Weyl’s proofs, that the theory must lead to exact equality of masses (See letter 17, note 4). This led Dirac to suggest in [Dirac 1931c] that there might be another positive particle besides the proton. In summer 1932 Carl D. Anderson announced the discovery of a light positive particle, which was soon identified with the Dirac hole and received the name ‘positron’. See [Hanson 1963, Moyer 1981b, Moyer 1981c, De Maria-Russo 1985, Kobzarev 1990].

³ Calculations of the Compton scattering of a photon on an electron required the existence of processes in which the electron passed through a transitional state with negative energy, which was not easy to interpret. Dirac in [Dirac 1930a, p. 365] thanks Ivar Waller for telling him about this difficulty. Waller in turn referred to an unpublished result of Werner Heisenberg [Waller 1930, S. 844]. Indeed, Heisenberg had shown that the negative energy states were crucial for deriving classical Thomson scattering formula (Heisenberg to Pauli, 31 July 1928 in [Pauli 1979, S. 468]).

The hole theory gave an interpretation to this fact, allowing electrons to go into the negative energy states. The remaining difficulty, which Tamm mentioned as the one he could answer by himself, was that the transitional state could be already occupied by another electron. Dirac explained in [Dirac 1930a, p. 365] that the scattering process would then require two electrons, one emitting and one absorbing, with the final result, the probability of scattering, remaining unaffected.

⁴ Tamm shared Dirac's hope that the interaction of the negative energy electrons would somehow explain the difference in the masses of the proton and the electron. Since electron in the process of Compton scattering passed through a negative state, the surrounding 'sea' of negative energy electrons could have influenced the result. In fact, the probability of scattering did not depend on the existence of other negative energy electrons.

⁵ In his paper [Tamm 1930c], Tamm used the formalism of the quantum electrodynamics from [Heisenberg-Pauli 1929]. The ε -term was used there to evade formal difficulties in the quantization of the electromagnetic field. In the final result it had to be put equal to zero. This method was criticized as artificial and was abandoned by Heisenberg and Pauli themselves in their second paper [Heisenberg-Pauli 1930]. Practical calculations with only the radiation field, without the Coulomb term, (the case treated by Tamm) could be carried out without the ε -term at all.

⁶ The so called 'Born-von Kármán periodic boundary conditions', first introduced for the case of vibrations in a crystal (1912). They provide a way of treating a system with a continuous set of degrees of freedom as if it were a system with the discrete set of degrees of freedom. In 1930s this method was not yet generally regarded as an unproblematic tool, therefore, Tamm mentioned it explicitly. He referred to the presentation of it in [Born 1922, §18].

⁷ [Tamm 1930b], where the apparatus of quantum electrodynamics was first applied to solid state theory (the Raman effect or Mandelstam-Landsberg molecular scattering of light), and where Tamm introduced the notion of quanta of elastic oscillations later called 'phonons'.

⁸ The correct formula of the Compton scattering was first obtained by Oscar Klein and Yoshio Nishina in [Klein-Nishina 1929] on the basis of semi-classical calculations. Tamm's deviating results were coming from a mistake which he would soon correct and arrive at exactly the Klein-Nishina formula (see letters 12 and 13).

More rigorous calculations of the Compton scattering in the quantum theory were carried out independently by three authors. Ivar Waller in [Waller 1930] (12 February 1930) used Dirac's theory of radiation of 1927; Dirac in [Dirac 1930b] (26 March 1930) used his general formulation of the quantum mechanics; and Tamm in [Tamm 1930c] (7 April 1930), relativistic quantum electrodynamics of Heisenberg and Pauli.

⁹ Tamm refers, perhaps, to [Skobelzyn 1929], dated 23 September 1929 and published in December 1929. See [Roque 1993] for the history of the derivation and testing of Klein-Nishina formula and [De Maria-Russo 1989] for discussion of the formula's role in the controversy over the nature of the cosmic rays.

¹⁰ Walter Bothe and Werner Kolhörster were first to argue in [Bothe-Kolhörster 1929] that cosmic rays besides the ultra-hard electromagnetic γ -radiation also contain charged particles.

¹¹ See note 3.

¹² Nizhniy Novgorod, in later Soviet times Gorky, a city on Volga. Leonid Evgen'evich Tamm (1901-1942), Tamm's brother, was a chemical engineer and worked at a large chemical factory in Rastyapino (in later Soviet times Dzerzhinsk). He was arrested at the height of purges, testified in one of the famous public Moscow trials of 1937, and disappeared in the Gulag archipelago.

21-2-30
St. John's College
Cambridge

Dear Tamm,

Many thanks for your letter.

I think it very remarkable that you should have found a different formula for the scattering of radiation by free electron. I have recently been looking into this question myself, and my work confirms the Klein-Nishina formula. I think you should still get this formula when you use the method of quantization of waves. Are you sure you have not made a mistake? Waller, so far as I know, has not been dealing with free electrons, but only bound ones (where the same difficulty of intermediate states of negative energy occurs). ¹

I have recently been working out the probability of an electron dropping into a hole and simultaneously emitting two light-quanta. The mathematics is very much the same as in the scattering problem — in one case there are two emissions and in the other one emission and absorption. The result I obtain is that when an electron meets a proton, the effective area that must be hit in order that they may combine to give radiation is of the order of magnitude of the classical size of the electron or proton. ²

I have finished writing the book and now have “Korrekturen” to deal with. I do not take so long over them as you did in Leiden. ³ Gamow has been riding a motor cycle, (I think he has written to tell you), and he has also been teaching me to ride it. ⁴

The air journey from Leningrad to Berlin was very enjoyable. Did you not get my previous letter?

Yours sincerely,

P.A.M. Dirac

¹ See letter 11, notes 3 and 8. Waller, in fact, calculated both the scattering on bound electrons in the first part and, following Pauli's advice, the scattering on free electrons (Compton scattering) in the second part of his paper [Waller 1930].

² This first calculation of the process of annihilation of the electron and the hole was published in [Dirac 1930b].

³ *The Principles of Quantum Mechanics*. [Dirac 1930e]. See also letter 3, note 1, and letter 5, note 3. In summer 1930 Dirac brought the proof sheets of this book to Kharkov (letter 15, note 1) and gave them Dmitriy Ivanenko for a Russian translation. The book, translated by Matvey P. Bronshteyn and edited by Ivanenko, appeared in 1932 [Dirac 1932e].

⁴ George Gamov held a Rockefeller fellowship from the International Education Board and was spending a year in Copenhagen and Cambridge. A photo of him with a motorcycle see in [Robertson 1979].

[13] TAMM TO DIRAC

3-3-30

Gerzen str 5, k. 12

Moscow, 7

Dear Dirac,

thank you very much for your letter: I have again to acknowledge your omniscience — I wrote you already in a card from the 23.II., that I *did* make a mistake in the calculations (a wrong sign of a sine!) & that the Klein-Nishina formula has not to be altered.

I was very much interested in what you write about the probability of the annihilation processes, especially as I was just working out this probability myself when I got your letter. ¹ Considering a free positive-energy electron & a “hole” in a volume

V , I find by a calculation, closely analogous to that made for the scattering, * that the probability of the annihilation taking place within a unit of time equals to

$$Z = \frac{\pi d^2 c}{V} f(\beta), \quad (1)$$

where d stands for the classical diameter of the electron ($d = \frac{e^2}{mc^2}$), & $f(\beta)$ is a function of the relative velocity $\beta = \frac{v}{c}$ of the electron & the hole:

$$f(\beta) = \frac{\gamma}{1 + \gamma} \left[\frac{1 + 4\gamma + \gamma^2}{2\beta} \log \frac{1 + \beta}{1 - \beta} - 1 - 3\gamma \right] = 1 - \frac{3}{20}\beta^4 + \dots;$$

$$\gamma = \sqrt{1 - \beta^2}.$$

The fact, that the expression (1) corresponds classically to the probability of collision between the electron & the proton having the relative velocity c , can perhaps be understood in connection with the fact, that the “velocity” $c\alpha_k$ has the eigenvalues $\pm c$.² But the main difficulties are: 1) if one (tentatively & approximately) applies the formula (1) to the case of bound electrons, one gets a ridiculously short <life> value for the life-time of an atom,³ & 2) the frequency of the radiation emitted, when an electron drops in a hole is of the order of magnitude of mc^2/h , where m is the mass of the electron & not of the proton, & that can’t be reconciled with the existence of the cosmic radiation.⁴

Of course these difficulties are of the same kind as the difficulty with the mass of the proton and are connected with the necessity to take in account the interaction of the negative-energy electrons, the disappearance of the field of the electron & of the hole <proton> when the electron drops in the hole and so on. But I can’t understand why one gets the correct scattering formula although one neglects all the complicating circumstances of this kind, connected with <the> transitions of the electron through the states of negative energy.⁵

Well, my conscience tells me that it is a shame to trouble you with all kinds of boyish questions.⁶

We have an exceptionally mild winter this year so that I could not use properly the “skies” (I don’t know the english name for the “snow-shoes”) I bought.

^{1*} These calculations are very much simplified when one combines in one matrix of 4 rows & columns the 4 sets of amplitudes of the 4 independent ψ -functions describing the <different> possible states of the electron having a given value of the impulse \vec{p} .

I never got your previous letter mentioned in your last one —it was the first I got since the summer. I know that some of the letters addressed to me got lost when I moved to the new lodgings in November last.

With best wishes & compliments, yours sincerely,

Ig[or] Tamm

¹ The following formulae were published in [Tamm 1930c].

² Gregory Breit had first pointed out that the most natural generalization of the classical variable of velocity in the Dirac's theory of electron is the operator $c\alpha_k$ [Breit 1928]. This operator, however, had only two eigenvalues $+c$ and $-c$, which looked like a contradiction with the requirements of relativity theory. The difficulty with the velocity of the Dirac electron was widely discussed for a while and later largely forgotten, after Schrödinger had published [Schrödinger 1930].

³ Tamm obtained the value about 10^{-3} sec for the hydrogen atom consisting of a proton and an electron [Tamm 1930c, S. 568]. This was another difficulty speaking against the identification of holes with protons [Dirac 1930d]. Another estimation can be found in [Oppenheimer 1930].

⁴ Independently of the hole theory and of quantum electrodynamics, cosmic ray physicists were discussing and later abandoned the idea of annihilation of protons with electrons as a hypothetical origin of cosmic radiation [Bromberg 1976].

⁵ See letter 11, note 4.

⁶ Apparently, Dirac did not have a satisfactory answer to these difficulties of the hole theory either.

[14] DIRAC TO TAMM

20-3-30

St. John's College
Cambridge

Dear Tamm,

Many thanks for your letter. I am glad you have got the correct Klein-Nishina formula now. Also your result for the annihilation probability is in agreement with my own (provided that by the probability per unit time you really mean the effective area that must be hit) so this is probably also right. * I do not understand why you say the m in the formula should be the mass of the electron and not of the proton. I should think it would be some sort of mean, as the theory is symmetrical between the electron and proton, and this would give the right energy for cosmic radiation. The theory at present predicts that an electron and proton should have the same mass, and is therefore inaccurate and unreliable in all questions where one has to take the different masses into account. I suppose the reason why the Klein-Nishina formula is right is because the process concerns only one particle, and not two interacting particles. ¹

In my previous letter which you did not receive I said I has sent 75 R.M. to the Hirschwaldsche Buchhandlung ² to be put to your account, as we agreed upon in Moscow. I hope you make use of it.

How is the motor-cycling going? I have been riding Gamow's motor-cycle, and have been filmed while doing so (so I have a positive proof).

With best wishes,

Yours sincerely,

P.A.M.Dirac

* I see on reading your letter again that V is volume and not velocity, which puts it right.

¹ Dirac was still reluctant to admit that the mass problem poses a fundamental difficulty. He published the idea of an intermediate value for the mass in [Dirac 1930b, p.375]. Tamm included it in his paper [Tamm 1930c, S. 547].

² A bookstore in Berlin. R.M. – Reichsmark.

6-7-30

Dear Dirac,

it is now the 4th day since I returned to Moscow, ¹ & nothing is settled yet in the respect to our expedition. This evening we hope to know definitely whether our English friends will be permitted to go with us to Alma-Ata. If not we probably will go to Caucasus, but it may be that in this case the Englishmen will simply return back to England & give up the whole business altogether. If so we may give up the expedition for this year & perhaps I will be able to meet you anywhere in the south. I am sorry to say that in any case the plan to meet you in the Baksan valley does not seem to be advisable. I will write you again within few days. ²

Yours sincerely,

Ig[or] Tamm

¹ Tamm sent this postcard to Kharkov, where at the end of June he, Dirac and several other theoretical physicists, including Walter Elsasser, Vladimir Fock, Yakov Frenkel and Dmitriy Ivanenko, had gathered for a small meeting at the Ukrainian Physico-Technical Institute. On his way to Kharkov, Dirac got in an incident. He chose another entrance point for crossing the Soviet border than that written in his visa and was held by the frontier guard for three days before the matter was settled.

² Tamm, together with mathematician Boris N. Delone, physicist Mixail A. Leontovich, astronomer Nikolay N. Pariyskiy, and two Englishmen, James H. Bell and H. M. Kelly, had been planning a trip to Tien-Shan mountains (present Kirgizia). Caucasus was their reserve possibility, and finally they went there (see letter 17). For a while, Tamm had entertained the idea that Dirac would join the group. Baksan is a river and a valley in the Caucasus.

[16] DIRAC TO TAMM

9-7-30

Kharkov

Dear Tamm,

Thanks for your card. There are also difficulties on my side which prevent the excursion we had planned for the Caucasus. The Soviet laws are such that if I stay in Russia for more than one month, then when I leave Russia I shall not be allowed to take away with me any foreign money (and of course no Russian money) so that I must make the return journey without money. To avoid this difficulty I must leave Russia within one month, that is not later than July 27th. Tomorrow Elsasser and I are going to Gagri, from where we shall make a number of excursions. Iwanenko is returning to Leningrad. I expect I shall leave Russia by the ship which sails from Odessa on July 22nd for Venice, as there is no later ship till August. If you write to me you can use the address Gagri, Poste restante (translated into Russian). ¹

With best wishes from

P.A.M.Dirac

I should be very glad if you could send me some stamps having the picture of Zamenhoff. Better address them to England. ²

¹ After the Kharkov conference, Dirac, together with German theoretical physicist Walter Elsasser, went to Gagry, a resort on the Caucasian Black Sea coast, present Abkhazia. He left the Soviet Union by airplane from Leningrad around 25 July (Dirac to Fock, 30 July 1930).

² In 1927 the Soviet Union issued a series of postage stamps commemorating the 40th anniversary of Esperanto, the language invented by L. Zamenhof.

13-9-30
Gerzenstr., 5, Wo. 12
Moskau, 9

Dear Dirac,

It was a very great disappointment to me not to be able to enjoy your company during your stay in Russia. But it could not be helped — I have had obligations towards my English friends I invited for mountaineering. On the other hand it proved impossible to arrange things in such a way as to meet you in the mountains at the end of the more strenuous part of the journey, as there were reasons to suppose that we will have to change the proposed route when staying in the mountains & having no means to communicate with you — this proved to be the fact & instead of going via Baksan to Abhasia we have had to go via Chegem to Suanetia. ¹ And — last but not least— when I returned to Moscow from Kharkov & discussed the situation, the exertions & dangers of the trip appeared to me in a different light as in Kharkov & I honestly felt no right to induce you to take part in the matter, although it was very hard for me to abandon the pleasure of your company.

My friend Mr. Bell was feeling himself ill for the most part of the journey — coarse diet, heat in the valley, exertion of carrying heavy loads & the primitive life in the open proved to be bad for him — so that he took part only in one ascension & insisted on going home long before the proposed date. He is a mountaineer of the very first class, but the conditions of mountaineering in Caucasus differ so much from those in the Alps that one has to have a special training to stay them.

Still for my own part I can by no means call the trip as unsuccessful one. We began with a first ascent on an unascended peak not very difficult & not very high (4300 mtr). But in about an hour distance from the summit we got in a heavy hail-storm, so that it became impossible to stay on the feet & we had to make the rest of the way creeping on the knees & hands & lying flat on the snow slope when especially strong storm blows came. But the most interesting thing were the local electric discharges — the ice-axes {... singing &} once as if pins were picked at the roots of the hairs on my head.

The second time we tried to ascend a rather easy peak (4200 mtr), but owing to

very bad {"fo.."} weather conditions had to return when in about 300 mtr from the summit. There was a great many avalanches on this day both on our peak & on the neighbouring ones. We hardly escaped one of them when crossing a snow couloir we started another. My friend who was leading (at that moment we were unroped) was taken in by the avalanche but at {least} 40 mtr lower, after passing 3 rock-steps he succeeded to grasp a rock & was saved — under him was a precipice. A real {miracle} especially as he was hardly {hit} at all. I was the second in the party, got a heavy blow by a stone at the back, but being near the rocks was able to grasp them & had just enough forces to keep steady. It was a hard experience & all of us got a kind of a psychological shock.

Still some days later three of us, Mr. Bell included, made a second ascension of a very difficult peak Bashil Tau (4180 mtr). Without Bell we simply could not attempt the ascent, but Bell did miracles — to that date I thought such climbing as he did a sheer impossibility, to be seen only in a movy-picture. I am not a coward & have 5 years mountaineering experience, but twice during the climb I was inclined to stop & stay back, not having the courage to climb *with the help of the rope*, fastened by Bell above the difficult place, where Bell climbed unaided by the rope! According [to] Bell the ascent was "sehr schwierig", judged by Alpine standards, more difficult for instance, than the ascent of Matterhorn. ²

At the physical congress in Odessa ³ I met Pauli & was very pleased to make his acquaintance. Pauli told us, that he rigorously proved, that the system consisting of m positive energy electrons & n "holes" in the distribution of negative energy electrons has the same energy as the system, consisting of m holes & n electrons, the electrons having the velocities which previously belonged to the holes and vice versa. Pauli concludes, that on your theory of protons <the effect> the interaction of electrons can't destroy the equality of the masses of an electron & a proton * . — I would be very much pleased to hear, that Pauli is wrong. ⁴

In Kharkov I discussed with you the possibility of the scattering of radiation by a pair of electrons, one electron absorbing the incident photon & the other emitting the

^{1*} Of course there remaining the escape to suppose that the number of electrons in the world is not equal to the number of holes, but it seems to be very artificial.

scattered one. I see now that such processes are impossible, since the terms of the sum

$$\left| \sum_{\alpha''} \frac{(\alpha' | v | \alpha'')(\alpha'' | v | \alpha')}{(E_{\alpha''} - E_{\alpha'})} \right|^2$$

cancel out pair by pair if the final states of the electrons are different from their initial states. Only in the case, considered by you in the "Theory of protons", i.e. in the case, when the final state of an electron coincides with the initial state of the other, can such processes take place. ⁵ I was very interested to find, that your statement: "the fact of an intermediate state of a double transition being occupied by a second electron does not alter the transition probability" can be proved only if one takes in account, that the wave functions of the electron contain "den Jordan -Wignerschen Vorzeichenfaktor"

$$\nu_m = \prod_{k \leq m} (1 - 2N_k).$$

Why did you not mention that in your paper? ⁶

I am finishing now a paper on the theory of selective photo-effect in metals & think the mechanism of it is quite different from that suggested by Fowler in his last paper. ⁷

Well, I have certainly to apologize for such a long & baldly written letter. With best wishes from your very sincerely,

Ig[or] Tamm

P.S. Please excuse me that I took so much time to send you the stamps. There is only one kind of stamps with the picture of Dr. Zamengoff — the stamps I send you differ only in the water-marks.

I was asked by our new Soviet Encyklopedia to write a biographical notice on you. Could not you be so kind as to send me a short autobiographical note with the permission to make use of it for the article?

And a second "Bitte": — could not you send me a reprint of your last papers in "*Cambridge Proceedings*"? ⁸

Yours Ig[or] Tamm

¹ Abkhazia and Svanetia – ethnic regions in Western Caucasus. Baksan and Chegem – valleys of the rivers with the same names.

² This ascent of Bashil'-Tau was the first in the history of the Soviet alpinism. Matterhorn (4477 m.) — famous peak in Alps.

³ The 7th Congress of Russian Physicists, also called the 1st Congress of Soviet Physicists, Odessa, 19-24 August 1930. It also turned to be the last congress, for the Soviet (Russian) Association of Physicists was dissolved the next year like a large number of other professional societies and interest groups. More on the congress and on Pauli's visit in [S"ezd 1930, Frenkel 1986a].

⁴ Wolfgang Pauli (1900 – 1958), physics professor at the Eidgenössische Technische Hochschule in Zürich. Pauli, together with Niels Bohr, was a strong critic of Dirac's hole theory. More on their criticism see in [Moyer 1981b],[Kragh 1990, p.112-114]. Even after the discovery of the positron, on 19 April 1933, Pauli wrote to Patrick M. S. Blackett: "I don't believe on the Dirac-"holes", even if the positron exist" [Pauli 1985, p.158].

Another proof that the masses of the electron and the hole must be equal was given by Hermann Weyl in [Weyl 1931, Kap.IV, §6].

⁵ On the last page of [Dirac 1930a], Dirac discussed the scattering by a pair of electrons, one with negative energy absorbing a photon and going into the region of positive energies, the other falling into its place with the emission of a photon. This was necessary in the hole theory in order to allow intermediate states filled with negative energy electrons to appear in the calculation of the scattering cross-section. Tamm considered the possibility of processes in which the final state of the second electron does not coincide with the initial state of the first one, and arrived at a negative conclusion. The calculation was published in [Tamm 1930d].

⁶ In his calculation, Tamm used the formalism of second quantization for fermions, as developed in [Jordan-Wigner 1928]. Dirac, although being one of the authors of the method of second quantization, was reluctant to use it and preferred to derive results from the symmetrical properties of the wave functions. [Kojevnikov 1990].

⁷ [Tamm-Shubin 1931c]. Tamm probably means [Fowler 1930].

⁸ [Dirac 1930b, Dirac 1930c].

[18] DIRAC TO TAMM

4-10-30

St. John's College
Cambridge

Dear Tamm,

Many thanks for sending me the stamps, and also for your long letter. I was very interested to read about your mountaineering exploits.

What you say about the impossibility of scattering by a pair of electrons is quite correct. I had not previously noticed it.

You say that "the fact of an intermediate state of a transition being occupied by a second electron does not alter the transition probability" can be proved only if one takes into account the *Vorzeichenfaktor*. This is not really true, because one can prove the result simply by using antisymmetrical wave functions. If one uses any other method, then one must see that this other method is mathematically equivalent to the antisymmetrical wave functions. The use of the *Vorzeichenfaktor* is thus not a new assumption. ¹

I am sending you reprints of my last two papers under a separate cover. I have only just received them.

On the next page is a short autobiography for the *Soviet Encyclopedia*. I hope it gives all you want. ²

With best wishes,

Yours sincerely,

P.A.M. Dirac

I was born in Bristol on the 8th of August 1902. I studied Electrical Engineering at Bristol University from 1918-1921 and Mathematics at Bristol University from 1921-1923. In 1923 I came to St. John's College, Cambridge, as a research student in theoretical physics, where I have been ever since except for short visits to foreign

countries. The chief of these visits are: Copenhagen and Göttingen throughout the year 1926–7; Volga congress in August 1928; five months in America in 1929, returning through Japan and Siberia. I took the Ph.D. degree in Cambridge in 1926, was elected a Fellow of St. John's College in 1927 and a Fellow of the Royal Society in 1930.

¹ See letter 17, note 6.

² This short autobiography provided the background for Tamm's and Ivanenko's biographical article on Dirac in the first edition of the Great Soviet Encyclopedia (Bol'shaya Sovetskaya Enciklopediya. T. 22. s. 505 (1935)).

[19] TAMM TO DIRAC

29-12-30
Gerzenstr. 5, Wo. 12
Moskau, 9

Dear Dirac,

Happy New Year & best wishes for 1931!

Many thanks for your autobiographical note & for the reprints & please excuse me not having acknowledged it till now. Somehow it turns out that I am mostly writing you on some special reason, & that is the case this time too.

I have reasons to believe, that I will be able to go abroad in April next for about 4 months, although the <business> question is by no means certain yet. Supposing I go, you understand, that it would be a great pleasure to me to work a part of the time (perhaps $1\frac{1}{2}$ to 2 months?) in Cambridge. Please write me whether that will suit you at all. And if so, could I ask you to send me a letter stating the possibility for me to work at Cambridge; such a letter, being shown to our authorities, would make it much easier for me to obtain the permission to go abroad. Or have I perhaps to take some special kind of steps to ask to be accepted in Cambridge?

Each autumn I hope to be able to spend more time on scientific work, and each year turns to be less favourable in this respect as the previous one. Since autumn last I have had just enough spare time for a paper on photoeffect in metals, which is just ready. ¹ In general I have realized, that the fundamental problems of the quantum theory are too difficult to be tackled by me & am occupied with the easier applications of the theory. In the last time I am specially interested in the theory of metals & would be very glad to get in personal touch with Prof[essor] Fowler, if I come to Cambridge at all. ²

Although we all are complaining of the lack of time, we are living now in Russia a very {absorbing} kind of life, becoming each month more intense & absorbing {yet}. Here you have quite a casual illustration of our trend of life. ³ I never thought it possible for a large body of students to work as hard as our students do now. Our last

year students have divided themselves on their own behalf in groups —“brigades”— of about five members of each brigade, working and studying together 9 days out of 10 (they decided to work on the second free day of the decade) ⁴ from 9 a.m. to 9 p.m. with a 2-hours interruption for meal (research work included, which is of course conducted individually by each student). Yesterday speaking with a brigade, I found them troubled with the fact, that they have “lost without any use” *six* out of 270 working hours of the last month! Of course this is an exaggeration, the students become overstrained and we, the University staff, are trying to make the things more sensible, but the whole business may give you an impression of the dominating tone of our life.

With best wishes from yours sincerely,

Ig[or] Tamm

¹ [Tamm-Shubin 1931c].

² Ralph H.Fowler (1889-1944), theoretical physicist, professor in Cambridge and Dirac’s former tutor. Worked on the applications of quantum theory to atomic spectra, radioactivity, solid state. In 1934 Tamm returned from the solid state theory to fundamental problems of nuclear and particle physics.

³ Tamm describes below some aspects of the so-called ‘cultural revolution’ of 1928–1931, in particular the campaign to educate quickly and in very large numbers the new technical elite, and radical leftist experiments in the field of education. The ‘brigade method’ was meant to replace the traditional lecture form of education. Students had to study actively, by themselves and in groups, with the professor available for consultations, not lectures. Traditional methods of education were restored in 1932, along with the general shift in politics from revolutionary to conservative [Cultural 1978].

⁴ In the course of the cultural revolution, traditional week was replaced for a while by a five-days week consisting of four working days and one day off.

[20] DIRAC TO TAMM

Dear Tamm,

I have enclosed a more official letter for the authorities. The summer term in Cambridge lasts from about April 20th to June 20th and this would be the best time to come here. I hope you will be able to come.

Yours sincerely,

P.A.M. Dirac

15-1-31

St. John's College
Cambridge

Dear Professor Tamm,

I was very glad to hear that you hope to be able to come abroad this Spring, and shall be most glad to have you working with me on the problems of the Quantum Theory. We have been very interested in your work on the annihilation of electrons and protons, and as I am working on this subject myself, it will be great value to me to discuss these questions with you here in Cambridge; especially as they have a bearing on Radioactivity and the Disintegration of Matter in general in which all the Cavendish Laboratory is very interested.

We should also be very glad if you could give some lectures to our Physics Club here. ¹

Professor Kapitza ² asks me to tell you that he is very anxious to see you here and discuss some questions of his theoretical work on Magnetism.

Kindly let me know when you are coming so that we can arrange the necessary visa to enter this country.

I am,

Yours most sincerely,

P.A.M. Dirac

¹ Most probably, the seminar started in Cambridge by Piotr Kapitza in 1923 and commonly known as Kapitza-Club. Dirac was its permanent member since 1924.

² Piotr L. Kapitza (1891-1981) – Soviet physicist who in 1921–1934 worked at the Cavendish laboratory in Cambridge, but then was forced to remain and continue to work in the Soviet Union. He was also a close friend of Dirac and corresponded with him a great deal [Dirac-Kapitza 1990b].

[21] TAMM TO DIRAC

22-1-31

Dear Dirac,

I thank you very much indeed for your most kind and flattering letter. I look with greatest eagerness for the possibility to come to Cambridge, but I am sorry to say, I don't suppose the question will be settled before March. Any how I will let you know as soon as there will be something certain. And of course I {took} notice of what you say about the duration of the summer term.

We will have winter vacation from 1st to 15th of February this year, but I won't be able to use them, as my son is fallen ill with scarlet-fever. The case is not very bad, but he is recovering far too slowly.

Please convey my best greetings to Mrs. & Mr. Kapitza.

Yours sincerely,

Ig[or] Tamm

[22] TAMM TO DIRAC

2-3-31
Gerzenstr. 5, Wo. 12
Moscow, 9

Dear Dirac,

It seems now to be almost certain, that I will be able to go abroad about the 15th of April. I shall stay for 3 days at Berlin, for another 3 days at Leiden & arrive at Cambridge about the 25th of April. You would oblige me very much in helping me with the English entrance visa.

My lodgings keep to function as a sort of infirmary —my son has recovered, but my daughter was ill & my wife is ill with pneumonia (the case is not very bad). ¹

I hope to finish in the next few days the calculations relating to the space-anisotropy of the radiation field of an atom radiating in an intense electric field, recently observed by Stark. ² The explanation of the effect is not quite so elementary, as I have thought at first.

My best regards to Mrs. & Mr. Kapitza. Hoping to see you soon, yours sincerely,

Ig[or] Tamm

¹ Tamm's son Leonid and daughter Irina.

² Tamm did not publish anything on this topic. He was probably referring to the paper [Stark 1930a]. In other, earlier and later publications, Stark connected his claim for the experimental discovery of the 'Axialität' of the emission of light with his theoretical rejection of the quantum theory and with his personal conflict with Arnold Sommerfeld (See for instance [Stark 1930b]). His papers were generally rejected by the quantum community and the conflict continued further along political lines. More information and references can be found in [Stark 1987, S. 67-80].

[23] DIRAC TO TAMM

9-3-31

St. John's College
Cambridge

Dear Tamm,

I have applied to the Foreign Office in London for permission for you to enter England, and have asked them to send this permission to the British Consulate at Moscow. You should therefore apply for your visa there. You can give Kapitza's name and my own as references.

Hoping to see you about April 25th,

Yours sincerely,

P.A.M. Dirac

[24] DIRAC TO TAMM

1-4-31

St. John's College
Cambridge

Dear Tamm,

I have just heard from the Foreign Office in London that they authorized the British Consul-General in Moscow to grant you a British visa, so you will not have any difficulty about it when you come to this country.

I should be glad to see you in Cambridge at any time until about the end of July, when I shall be leaving for America.

Yours sincerely,

P.A.M. Dirac

Tamm's Visit to Cambridge

Tamm left Moscow on 29 April 1931. The story of his visit will be again told mainly by letters he wrote to his wife.

“Berlin, 1 – 2 May, Leiden (Holland), 3 –7 May. On the invitation of the Institute of theoretical physics I stayed a bit longer in Leiden to give a talk at the institute's colloquium and to meet with local scientists. ... I acquainted myself with the new researches on the theory of metals which are going on in Leiden and also in Groningen (Pr[ofessor] R. de L. Kronig came to meet me) ¹ ... London, 8 May, Cambridge from 9 May to 3 July with several visits to London and other places during this period” (Tamm's official report of the trip, 21 October 1931 [Tamm 1986, s. 99-100]).

“My business is making rather slow progress yet — I have not yet been attracted by anything particular, and generally there is at the moment a lull on the theoretical front. But I got many impressions of life here... On the 14th, Dirac took me to London in his car (he is a good driver), to the meeting of the Royal Society. ... The meeting started with the “introduction” of the newly elected members to the Society, and during the ceremonies their names were written in the ancient folio with the name of Charles II on the first page. I was greatly taken with Rutherford...” ²

“Always questions about Russia... 13.V. Dirac invited me to breakfast at his room for a talk about Russia with one of the college fellows (ancient philosophy and literature). ³ The conversation turned mainly upon the question, why we don't want to pay pre-war debts, then generally upon politics. We disputed for $4\frac{1}{2}$ hours, and I even became hoarse. The dispute ended, ... like one in Leiden, with a joke “these Russians are ostensibly coming here to visit but in reality they make propaganda”. But seriously, I have a feeling that Dirac is not very happy with my talks and in particular with the forthcoming speech in London, on 29th, about “Higher education in Soviet Russia”, although I had consulted him before I accepted the invitation. When I showed

¹Ralph de Laer Kronig (1904 –), American theoretical physicist. Tamm met him in 1928 in Leiden, where Kronig was spending part of his Rockefeller fellowship (International Education Board). After visiting various places in Europe, Kronig settled finally in Holland. In 1930 – 1939 he was a lecturer at Groningen University.

²Sir Ernest Rutherford (Baron of Nelson and Cambridge) (1871 – 1937). At the time of Tamm's visit, Rutherford was professor at Cambridge University, director of the Cavendish laboratory, and president of the Royal Society of London.

³Probably M.P.Charlesworth, see letter 26, note 4.

him the printed announcement of my talk, he expressed a hope that the talk would be on education rather than on politics” (Cambridge, 18 May 1931).

“Thursday evening Dirac suggested that I make a rush calculation in connection with his new work, and I have been calculating for $3\frac{1}{2}$ days without an interruption, ‘like mad’, and finished just in time — Dirac refers to my result in his paper and I will publish a short note, 4–5 pages. This is not a physical but a pure mathematical work, but I already have several further ideas, more physical, which could turn out to be interesting, although Dirac looks a little bit sceptical, regarding not the ideas as such but the possibility of carrying out the corresponding difficult calculations.”⁴

“I was done with the work on Monday, and on Tuesday, yesterday, presented my paper (the one with Shubin)⁵ to the Physical Society. ... My London talk is the day after tomorrow,... it is announced in *Nature*. By the way, I have apparently overestimated Dirac’s dissatisfaction with this forthcoming talk — it seems that everything is all right...”

“Dirac often comes to me after lunch with his car, and we go far away from the town, leave the car in a field and walk together. I teach him how to climb difficult trees, he makes good progress, but I get damned dirty every time... Bell invited me to visit Scotland and go to the mountains there. I have persuaded Dirac ... and hope that we two shall travel to Scotland after June 20” (Cambridge, 27 May 1931).

“I shall spend a week in Scotland — in the mountains and in Edinburgh with Bell, then taking a steamer directly to the continent. ... If for any reason I don’t go to Jordan, I will go to another place in Germany — Leipzig (Heisenberg) or Göttingen. During the last period I am dreaming much of coming, even if for a short stay, to Bohr in Copenhagen — I always wanted this, but I thought that it was impossible. Copenhagen is the Mecca of theoretical physics, and Dirac’s stories about Bohr have roused me a lot.⁶ It seems that Bohr is the only one whom Dirac considers to be higher and stronger than he himself. Unfortunately, this dream can not be realized this time — perhaps, later I shall have more luck” (Cambridge, 12 June 1931).

⁴[Tamm 1931d] and [Dirac 1931c]. Dirac introduced in his paper the idea of magnetic monopole, and Tamm calculated the eigenfunctions of an electron in the field of a monopole.

⁵[Tamm-Shubin 1931c]. See also letter 17, note 7. Semen Petrovich Shubin (1908 – 1938), Tamm’s student at Moscow University, worked on solid state theory. After 1932 at the Ural Physico-Technical Institute in Sverdlovsk. In 1938 arrested and died in prison camp.

⁶More about the role of Bohr’s Copenhagen institute of theoretical physics as the center of quantum theory in [Robertson 1979, Aaserud 1990].

“I am writing in a hurry — Bell and Dirac are waiting for me — we are leaving in a moment. We left Cambridge the day before yesterday and yesterday arrived at Bell’s. We spent 5 hours in Edinburgh, can you imagine that I did not recognize my university? ⁷ We were walking around for half an hour and I recognised it only after Dirac asked a policeman. We are going now to the Hebrides — to the most beautiful island Skye” (Auchtermuchty, 25 June 1931).

“After Cambridge, the people here and the town — although it is very old — seem gray, boring and cold. Jordan and his family are very nice, but the whole mood of life here is somewhat prim, like in pre-war Germany. One feels very definitely that Rostock is a Junker and a fascist town. ... Once I came across a bookstore with show-windows full of anti-semitic literature, whose titles ... were not weaker than the literature of the Union of Russian People.” ⁸

“Generally speaking, I should not have come here. There is nobody here except Jordan. ⁹ Jordan is interesting, of course, but he has not been working very intensively during the last period. ... I shall give a talk at the colloquium here on Thursday about Dirac’s and my work, but I myself am not in a working mood. I think I am getting bored of staying abroad” (Rostock, 12 July 1931).

“In Cambridge I acquainted myself with almost all the researches in theoretical physics which are going on there. Of particular importance for me was close contact and cooperation with Dr. Dirac — one of the leading modern physicists — and our talks on principal problems of the quantum theory ... I wrote a paper in Cambridge which is connected with the latest work of Dirac — “On generalized spherical functions etc...”. Its task was to study mathematically the movement of an electron in the field of an isolated magnetic pole. The classical theory denied the possibility of such poles, but recently Dirac has proved that their existence does not contradict the quantum theory and suggested that they can play an important role in the building of heavy nuclei...”

“Rostock — from 8 to 29 July. Of particular importance in Rostock was the work with Pr[ofessor] Jordan on the problems of quantum theory. Because of the very short time available, we developed the mathematical side of the question only, while

⁷Tamm studied at the University of Edinburgh in 1914.

⁸Soyuz Russkogo Naroda — one of the two main anti-semitic political organisations of the last decade of the Russian Empire.

⁹Pascual Jordan (1902-1980), one of the authors of quantum mechanics, in 1929 – 1943 professor at Rostock University.

the most important applications of these methods to the physical problem remain for future work. The physical problem is to arrive at a real, not just formal, synthesis of the theories of quanta and relativity. Our mathematical work consisted in constructing a non-associative algebra (more precisely, algebra with weakened associativity), which from our point of view will be necessary for solving the above physical problem ¹⁰ ...” (Tamm’s report, 21 October 1931 [Tamm 1986, s. 99-100]).

¹⁰ Jordan introduced non-associative algebra in a hope to find an essentially new ground for developing the relativistic quantum theory. The idea came from an analogy with the way in which non-commutative algebra had paved the way to quantum mechanics in 1925. Later in 1931 Jordan wrote Tamm in a postcard that he had come to a conclusion that this mathematics could not be applied to real physical problems. However, in mid-1930s he returned to the idea of non-associativity and published several papers on it [Jordan 1933, Jordan 1934]. Although non-associative algebras have not given much to physics, they have developed into a special branch of mathematics.

[25] DIRAC TO TAMM

30-7-31
6 Julius Rd
Bishopston, Bristol

Dear Tamm,

There have not been any letter coming to me for you.

I enjoyed your stay in Cambridge very much, and also the climbing, and hope you will come to England again some time.

I am leaving tomorrow for America. I shall first spend about 6 weeks in the mountainous districts in the West and then return to Princeton.

With best wishes,

Yours sincerely,

P.A.M. Dirac

31-12-31

Moscow, 9

Gerzen str. 5, Wo. 12

Dear Dirac,

Happy New Year and much luck for you! I am really much ashamed to send you my congratulations in the last day of the old year only and even much more ashamed of not having written to you since Cambridge at all. I don't quite know how it happened at all. After my return to Moscow in August there was not very much to write about. I have had very much to do in the University, where the number of students and research students increased very considerably this year and where besides lecturing I have a considerable amount of general administrative work to do. I detested this kind of work, but someone has to do it. ¹ As a consequence I have had no time for physics; all I did were some minor considerations about metals. ² Besides I have had to prepare a new enlarged & revised edition of my book on electricity, the proofs of which gave you some occasions for jokes about me in 1928. I have not had time even for sport and did not yet use skis this year.

I hope that I will have more time in the spring, since the larger amount of my lectures end on the 1 of February.

I think you must be back to Cambridge by now. How did you enjoy your American trip and especially the Rocky Mountains? Did you become an experienced mountaineer and has your zeal for mountaineering increased? Also I would be glad very much to hear about what you are doing at present in physics.

I have had a nice time in Rostock. Jordan and his wife were very kind to me and I took part in Jordan's investigations about "ein Algebra mit abgeschwächten Associativgesetz, $A(BC) \neq (AB)C$." It is an idea of Jordan that this new kind of Algebra will be the adequate form of mathematics to tackle the problem of relativistic quantum mechanics, since it corresponds to a definite uncertainty of measurement of a *separate* dynamical variable (the conjugate one being left out of consideration.) Whether this idea will prove to be right or wrong is questionable, but the mathematical work itself was quite pleasing. ³

Nevertheless it was rather a fault of mine to go to Rostock after Cambridge, since after Cambridge any other place was bound to prove somewhat dull. I will always remember my stay in Cambridge with the greatest pleasure and wish to thank you very much for the nice time I have had there.

Hoping that you will excuse me my long silence and asking to be kindly remembered to Mr. & Mrs. Kapitza, Mr. Charlesworth ⁴ and all who remember me,

yours very sincerely

Ig[or] Tamm

¹ In 1930 Tamm rose to the position of professor at Moscow State University. In 1931, in the course of the general reforms in education, the physico-mathematical department of the University was split into several specialized departments corresponding to different branches of the natural sciences, among them physics department. Departments consisted of chairs (*Kafedra*), which were not just professor's chairs, but administrative units with several professors, docents and assistants. In 1931 Tamm organized and became the first director of the *Kafedra* of theoretical physics.

² [Tamm 1932d].

³ See pp. 56-57. 'Uncertainty of measurement' was the expression with whose help theoretical physicists of the Copenhagen circle were explaining their problems with relativistic quantum theory (the negative energy states of the Dirac electron and the newly discovered divergencies in interaction energy). Several papers, for instance [Jordan-Fock 1930, Landau-Peierls 1931], argued that the ground for encountered difficulties in quantum electrodynamics were more strict limitations on the possibility of measurement in the relativistic domain in comparison with the case of non-relativistic quantum mechanics

⁴ Dr. M.P.Charlesworth, Cambridge historian of antiquity.

[27] DIRAC TO TAMM

21-1-32

St. John's College
Cambridge

Dear Tamm,

Thanks very much for your letter. I have just got back from America. I had an interesting time in Princeton and learnt a good deal of pure mathematics there (about group theory and differential geometry) which I must now try to apply to physics. ¹

I enjoyed myself very much in the Rockies, although I did not do any difficult mountaineering but mostly kept to the trails. The scenery is very fine, particularly in the canyon country, which I visited after Glacier Park. ²

Charlesworth sends you his kind regards. He remembers you very well and is always talking at dinner-time about the tree-climbing expedition we had together.

With best wishes,

Yours sincerely,

P.A.M. Dirac

¹ Dirac lectured at the Princeton University in the fall term of 1931. He contacted there with physicist Eugene P. Wigner and mathematician Oswald Veblen. More on Dirac's American trip in [Kragh 1990, p. 106-107].

² See reminiscences about this trip in [Van Vleck 1972].

[28] TAMM TO DIRAC

19-8-32

{Z}oobzov, on the Upper Volga ¹

Dear Dirac,

I am very much ashamed indeed not having written to you for quite an eternity, not even having thanked for the separate; ² but I always was a very poor correspondent.

I was very glad to hear that you come to the Leningrad Conference in September and looking very much for the meeting. ³ I hope this time you will stay with me some days in Moscow after the Conference. In truth, my lodgings are *very* uncomfortable in many respects, but anyhow you will have a separate room for yourself.

That is the first summer since 1926 that I could not manage to go to mountains. Bell has gone with our friend Delaunay to Caucasus, ⁴ and I have had to stay back. However I do intend to take a revenge next year in Central Asia. ⁵ I am living with my family in a small village on the upper part of Volga; the place is very nice indeed. Only once we did interrupt the quiet {train} of village-life — have gone in a boat about 200 km ; it took 6 days of rowing and camping in the woods on the banks; the weather was fine and the whole party quite a success. Most of the time I was busy with the second edition of my book on Electricity — this damned book does not leave me alone; but anyhow I managed practically to write it a-new. ⁶ Yesterday I sent it to the publishing office and began to write a paper on the “Austrittsarbeit der Elektronen aus Metallen”. ⁷

Well, I hope to see you very soon again.

Yours sincerely,

Ig[or] Tamm

P.S. Could I ask you to bring me from abroad some drug against the head-ache? My wife has often very severe “migraines” (head-ache) and the usual medicines don't help her. There is a very good German patented medicine “Eu-Med, by D^r Tell and Co”. Perhaps it is to be found in England, if not, I think there must be some English equivalent, pyramidone & aspirin. I will be very thankful {if} you could {manage} it.

Ig[or] T[amm].

¹ Probably the town Zubcov near Kalinin (Tver') on Volga, North from Moscow.

² Probably [Dirac 1932b] (Note 3).

³ In September 1932 the Leningrad Physico-Technical Institute organized a conference on theory of metals. Dirac attended it and gave a talk on a different topic — his new approach to quantum electrodynamics, an attempt to solve its difficulties [Dirac 1932b]. At the conference Dirac met Vladimir Fock and Boris Podolsky who were already working on the further development of his new theory. As the result of their joint efforts came what was in a certain sense a more convenient new formulation of quantum electrodynamics, but not a desired breakthrough. It was published in [Dirac-Fock-Podolsky 1932c] and became eventually known as the 'many-times-theory'. See [Kojevnikov 1990] and Dirac-Fock-Podolsky correspondence in [Dirac-Fock 1990c] for details.

⁴ Boris N. Delone and James H. Bell, Tamm's companions in earlier expeditions. See letter 15, note 2.

⁵ In 1933 Tamm took part in an expedition in the Central Tien-Shan. See reminiscences of this expedition in [Sasorov 1986].

⁶ [Tamm 1932e]. See also letter 5, note 3.

⁷ [Tamm-Bloxincev 1933b].

[29] DIRAC TO TAMM

26-9-32

Sanatorium K.S.U.

Gaspra, Crimea ¹

Dear Tamm,

I expect to arrive in Moscow on the morning of the 9th Oct[ober] on the train from Kharkov, and am afraid I must leave Moscow by air for Berlin on the 10th Oct[ober] (one day later than I planned in Leningrad). I should be very glad if you would reserve a place in the aeroplane for me on the 10th Oct[ober]. My visa is already in order. I hope you will excuse my staying such a short time in Moscow, but it is so pleasant in Gaspra and you will understand I want to stay here as long as possible. I shall leave on the 5th Oct[ober] and will probably spend two days in Kharkov on the way, if they are having a theoretical symposium there. ²

I wish you were here in Gaspra so that we could do some climbing together.

Will you please write to me and let me know if you can reserve the place in the aeroplane. Hoping to see you soon,

Yours sincerely,

P.A.M. Dirac

¹ After the Leningrad conference, Dirac and Piotr Kapitza took a vacation in Gaspra near Yalta (the Crimea). K.S.U. probably refers to the government Commission for Assistance to Scientists (Komissiya Sodeystviya Uchenym pri Sovete Narodnykh Komissarov SSSR). Created in 1920 in order to distribute rations in the time of starvation and the Civil War, it continued to run sanatoria and other social and cultural institutions for the scientific elite.

² On his visit to Kharkov Dirac agreed with Boris Podolsky about the writing of their joint paper with Fock [Dirac-Fock-Podolsky 1932c] (See letter 28, note 3). Podolsky in Kharkov wrote the first draft and agreed upon the final version with Dirac in Cambridge and Fock in Leningrad by mail [Kojevnikov 1990].

[30] TAMM TO DIRAC

5-6-33

Moscow, 9

Gerzen str. 5, Wo. 12

Dear Dirac,

I always was a bad correspondent, but with years I am becoming worse and worse. I feel very acutely all the disadvantages of this my shortcoming, as I loose the contact with all people, even those most dear and interesting to me.

Many times this year I was about to write you, especially after Blackett's and Occhialini's paper appeared. ¹ I got used to say, that your prediction of the antielectron has no parallel in the history of science. One can think about Leverrier and Adams, but your case is different. ² Your theoretical prediction about the existence of the antielectron, being unstable in the "ordinary space" outside the nucleus, ³ seemed so extravagant and *totally* new, that you yourself dared not to cling to it and preferred rather to abandon the theory. ⁴ And now the experiment unexpectedly proved you to be right and even <gave you> presented you with the neutron, to make the "hole" stable with and to form a proton! ⁵

One often hears people to say, that the unobservable negative electrification of the world, produced by the negative energy electrons, is a metaphysical notion. I personally am also inclined to think, that this notion in its present form will find no place in the future structure of physics, but nevertheless I think one has to use this notion and work with it. ⁶ The notion of the immovable and unobservable ether, formed by Lorentz about 1890, was also a metaphysical one and was banned from physics in some 15 years by Einstein, but the Lorentz transformation and other premises for Einstein's work would be hardly established, if one did discard this notion right from the beginning.

I personally am very much dissatisfied with the academic year now ending. There were many external <reasons> circumstances interfering with my work. Among others we started last autumn a new theoretical section in our institute and I have had much to do with a number of new research students, who may prove to be helpful some time, but now take much care and work. ⁷ But apart from external reasons some internal one must be admitted to explain my almost perfect scientific sterility during the whole

of the year. I am rather in a somewhat depressed state and all my hopes are that the expedition I am taking part in will somehow revive me.

This year I am at last going to Tian-Shian in {Middle Asia} Central Asia, what I longed for during many years. The expedition has to explore a practically unknown mountain region at the Chinese frontier to the South of Chan-Tengri. ⁸ It consists of two geological parties and a mountaineering section, me being a member of this section. Most of the work will be hard rock climbing, but the exploration and if possible ascensions of two high peaks of about 6500 mtr. is also planned and I am to take part in one of these ascensions. We <alpi> mountaineers have also to do some work for the geologists. I leave Moscow with the last party in the beginning of July and am to return about the 15th of September. I am very enthusiastic about all this.

In January I went with my wife for a fortnight to the Cola Peninsula and Murmansk across the Polar Circle. We were not lucky enough to see the Aurora Borealis, but I enjoyed the Far North very much and among other things made some splendid skiing the snow mountains there.

My best regards to Fowler, Blackett, ⁹ Kapitza and specially to Charlesworth. Does he and you remember how we three of us played the part of wondering knights and saved a beautiful lady with a crying child out of the wrecks of her auto and from the hands of an unmerciful gipsy gang?

Yours very sincerely,

Ig[or] Tamm

¹ Although Carl D. Anderson was first to announce in September 1932 the existence of a positive particle with a mass much smaller than the mass of proton [Anderson 1932], many Soviet physicists either did not pay attention to his short note in *Science*, or did not find it very convincing. They were connecting the discovery of the positron with the half-a-year-later paper by Patrick M. S. Blackett and Giuseppe P. S. Occhialini, which published many photos with tracs of positive electrons and interpreted them from the point of view of Dirac's hole theory [Blackett-Occhialini 1933]. More on the discovery of the positron in [De Maria-Russo 1985].

² Tamm compares Dirac's prediction with the famous story of the prediction of the planet Neptune by U. J. J. Leverrier and J. C. Adams and of its subsequent discovery by J. G. Galle in 1845 – 1846. On this discovery see [Smith 1989] and literature cited there.

³ The present point of view is the opposite: positron is stable as free particle. Tamm could borrow this statement from [Blackett-Occhialini 1933, p. 714], where it was used as the explanation of why positron had not been observed earlier.

⁴ This interesting fact is not recorded in other available sources. Tamm could have this idea from the discussions with Dirac either in Cambridge in spring 1931, when Dirac first mentioned anti-electron in [Dirac 1931c], or in the Soviet Union in September 1932.

⁵ Neutron was first announced in February 1932 by James Chadwick. At first it was often taken to be a complex particle consisting of a proton and an electron; the idea that neutron is an elementary particle on par with proton was gaining popularity gradually in the course of about two years [Pais 1986, p. 409-412]. The hypothesis that proton is a complex particle was discussed much less often, but it appeared, for instance in [Anderson 1933, p. 494].

⁶ This was the opinion of many physicists of the Copenhagen circle. Tamm could also hear it from Vladimir A. Fock, who did not like the notion of the 'sea of negative energy electrons' and expressed this in a letter to Dirac on 12 February 1930 [Dirac-Fock 1990c, s. 178] and also in September 1933 at the 1st All-Union Conference of nuclear physics in Leningrad [Atomnoe yadro 1934, s. 144-145].

In 1934 Fock and Heisenberg developed symmetrical formulations of the theory of electrons and positrons without the use of the 'negative sea'. Dirac, however, continued to use his hole theory as the realistic description. Throughout the 1930s, the choice between two ways of presenting the theory was the matter of taste; in the post-war quantum electrodynamics hole theory became much less popular.

⁷ Graduate studies (*aspirantura*) were being gradually introduced in Soviet universities and research institutes after 1925. *Aspirant* was then something like an apprentice researcher. Writing a thesis became necessary only after 1934, when the abolished in 1918 academic titles were re-established again.

⁸ See reminiscences of this expedition in [Sasorov 1986]. Before the discovery of peak Pobeda in 1943, Khan-Tengri (6995 m) was regarded as the highest mountain in Tien-Shan.

⁹ Patrick Maynard Stuart Blackett (1897 – 1974), worked in the Cavendish laboratory. Tamm met him in Cambridge in 1931.

[31] DIRAC TO TAMM

19-6-33

St. John's College
Cambridge

Prof. Ig[or] Tamm
Moscow 9
Gerzenstr. 5, Wo 12.
U.S.S.R.

Dear Tamm,

Thank you very much for your letter. I ought to have written to you but I am also a bad correspondent (worse than you) and continually postpone my letter-writing.

Charlesworth and I both remember very well your visit to Cambridge and we both hope you will come again soon. Do you remember our tree-climbing? I cannot induce Charlesworth to climb trees with me now. He says he will not climb any more until you come to Cambridge again.

Physics is advancing more on the experimental side than the theoretical at present, but I continue to hope the theorists will have their turn again soon. I am like you in feeling dissatisfied with my research work during the past year, but unlike you in having no external reasons to blame it on.

It is very nice to have symmetry between positive and negative electricity in experimental physics again. Most theoretical physicists, e.g. Pauli and Bohr, do not like my hole theory at all. ¹ The theory now has additional support from the experimental discovery of the production of anti-electrons simply by letting hard γ -rays fall on a heavy atom. ² The process is so simple that it seems likely that the nucleus is not involved in it, but that there is simply a kind of photo-electric effect, one of the negative-energy electrons moving in a hyperbolic orbit near the atom getting raised to a positive-energy state and leaving a hole or anti-electron in the original hyperbolic orbit. Peierls, who is now in Cambridge, has been working theoretically at this effect, and gets the right order of magnitude to agree with the observations. ³

In your letter you spoke about the anti-electron and neutron forming a proton. This will not really do, as the spins are not right for it, in just the same way in which the spins are not right for forming a neutron from a proton and electron. ⁴

I hope you have a very good time on your expedition and succeed in getting to the top of your 6500 m mountain. (The Everest climbers are not meeting with much success at present.) ⁵

With best wishes from

P.A.M. Dirac

¹ See letter 17, note 4.

² [Blackett-Occhialini 1933, p. 716] first mentioned the possibility of the positron creation in the process of scattering of γ -quantum by atomic nucleus. The effect was reported by several groups of researchers in March – May 1933 (J.Chadwick, P.M.S.Blackett and G.Occhialini in Cambridge, L.Meitner and K.Philipp in Berlin, I.Curie and F.Joliot in Paris, C.D.Anderson and S.H.Neddermeyer in Pasadena, D.V.Skobeltzyn in Leningrad).

³ Rudolf Peierls (1907 –), German, after 1933 British physicist, worked mainly on solid state theory, but in 1933 – 1935 also on Dirac's hole theory. Apparently, he did not publish these calculations.

⁴ According to quantum mechanics, a combination of two particles with spin $1/2$ cannot give another particle with spin $1/2$, but only with 0 or 1. In 1933, however, the neutron spin was not yet determined experimentally, although data on nuclear spectroscopy strongly suggested the value $1/2$ [Pais 1986, p. 411].

⁵ The British expedition led by Hugh Rutledge tried to ascent Everest in May 1932 but decided to return on the 1st of June because of the bad weather conditions.

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Abbreviations

AJP	American Journal of Physics
AP	Annalen der Physik
BB	Preussische Akademie der Wissenschaften, Phys.-Math. Klasse. Sitzungsberichte
HSPS	Historical Studies in the Physical Sciences
JETP	Jurnal Eksperimental'noy i Teoreticheskoy Fiziki
PCPS	Proceedings of the Cambridge Philosophical Society
PNAS	Proceedings of the National Academy of Sciences, Washington
PR	Physical Review
PRS	Proceedings of the Royal Society of London, Series A
PZ	Physikalische Zeitschrift
PZSU	Physikalische Zeitschrift der Sowjetunion, Kharkov
UFN	Uspexi Fizicheskix Nauk (Soviet Physics Uspekhi)
VIET	Voprosy Istorii Estestvoznaniya i Texniki
ZP	Zeitschrift für Physik

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