Pieter van Musschenbroek (on the tercentenary of his birth)

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The contribution of the Dutch scientist, pedagogue, and maker of scientific instruments Pieter van Musschenbroek (1692–1761) to the science of electricity is presented. Biographical information is given. Special attention is paid to the associations of Musschenbroek with Russia.

One of the poetic compositions of G. E. Lessing (1729–1781) mentions the name of Musschenbroek[1)] (Ref. 1, Vol. 1, p. 216) along with such names as Newton, Leibnitz, and Euler, which speaks of the significance that was accorded to the Dutch scientist in the 18th Century. Musschenbroek contributed to all branches of experimental physics of his time, but his role was especially great in the development of the science of electricity.

Having become interested in electricity, Musschenbroek repeated for about three weeks the entire set of electrical experiments then known.[2] In his early works such as the "Elements of Physics" (1734),[3] Musschenbroek pays little attention to electricity, but subsequently the scientist devotes himself ever more to this field of science, then new. Thus, in the preface to the serial publication of the physics course titled "Precepts of Physics" (1748),[4] Musschenbroek writes: "Primarily the chapter on electricity has been polished, since up to now many distinguished philosophers have applied much inventiveness and care to these themes."

We can summarize as follows Musschenbroek's scientific methodology as presented by him in his early works.

We can recognize an object and its properties only by observations and experiments. But one must be very careful, use good instruments, and take account of all circumstances: the temperature, the atmospheric pressure, etc. Thus we can discover the laws of change of objects under the condition that the results of repeated experiments are the same. Thus Musschenbroek insists on induction, but adds a reference to Newton that also deduction is admissible, e.g., by using mathematics, provided only that the conclusions are invariably confirmed by experiment. Just like Newton, Musschenbroek did not love hypotheses, preferring the presentation of facts to them.[5]

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The Dutch scientist assigned great importance to the quantitative method. Thus, in 1725 Musschenbroek made an attempt (indeed, later subjected to just criticism) to find the quantitative law of magnetostatic interaction as a function of the distance between the magnets (Refs. 6 and 7, pp. 88–93).

In 1733 Charles-Francois de Cisternai Du Fay (1698–1739) discovered two forms of electricity—"vitreous" and "resinous," or, in the later terminology of Benjamin Franklin (1706–1790), positive and negative.[8,9] This discovery was anticipated by Musschenbroek's remark that glass and amber differ in "their" forms of electricity (they are electrified in different ways) (Ref. 7, p. 242). Du Fay,[8,9] who had deeply occupied himself with the history of the subject, knew, of course, this remark of the Dutch scientist.

The name of Musschenbroek has been continually associated with the first electric condenser—the Leyden jar, which was invented in 1745. The Leyden experiment

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(discharge of the condenser through the body of the experimenter) was a scientific sensation of the 18th Century; all were delighted by the long, bluish spark and were amazed by the "electric shock" in the discharge of the Leyden jar, which was charged with an electric machine; the connoisseurs valued the ability of the Leyden jar to accumulate electricity and keep it for a long time.

In modern terminology the dielectric of the first condenser was glass (Du Fay had used the insulating properties of glass in experiments on transfer of electricity at a distance),[10] while the plates were the experimenter's palm holding the vessel and the water in the vessel [Gray,[11] Gordon (Ref. 12, p. 37), and Bose (Ref. 7, p. 313)] had occupied themselves with extracting sparks from water). The lead to the inner (water) plate was a metallic wire dropped into the vessel and immersed in the water (Gray had discovered the electrical conductivity of metals).

We cannot consider the priority of discovery of the Leyden jar to have been finally elucidated. Without entering into a discussion on priority, we note only that in France and many other countries people first knew of the Leyden jar from Musschenbroek's letters from Leyden to Paris to René-Antoine de Réaumur (1683–1757), who in January 1746 reported on the letter to the Paris Academy of Sciences. In the proceedings of the Academy for 1746, Jean-Antoine Nollet (1700–1770) published a French translation of the experiment from this letter, which was written in Latin.[13] Nollet introduced the terms "Leyden experiment" and "Leyden jar".

"I wish to report to you," wrote Musschenbroek to Réaumur, "on a new, but terrible experiment, which I advise you not to repeat yourself in any case. . . I have performed some studies on the force of electricity. For this purpose I suspended on two blue silk cords an iron shaft, having transmitted electricity to it from a glass ball, which was rapidly rotated about its axis, and to which I simultaneously applied my hands, thus rubbing it; from the other end a brass wire was hung, the end of which was immersed in a round glass vessel partly filled with water, which I held in my right hand, while with the other hand I tried to extract sparks from the electrified iron shaft; unexpectedly, my right hand was shocked with such force that my whole body shook as from a lightning bolt."[13]

In his letter to Réaumur, Musschenbroek erroneously attributed the success of the experiment to the use of only German or Bohemian glass, while noting that with vessels of other glass the effect was weak or completely absent. Upon acquainting himself with Musschenbroek's letter, Nollet immediately was the first in France to repeat the Leyden experiment and to show that the source of the glass was inessential (Nollet possessed neither German nor Bohemian glass).

Musschenbroek's letter contains a remark that has not attracted the attention of historians: "If you put the vessel on a metallic support on a wooden table, then, by touching the metal only with the end of your finger and extracting the spark with the other hand, you receive a very strong shock." The metal support here fulfills the function of a plate of the condenser, ridding the experimenter of the need of using his palm as the plate during charging. In this experiment only the bottom of the vessel serves as the condenser dielectric, but progress in understanding the role of the plate and the corresponding technical solutions did not have to wait long: soon a Leyden jar with foil plates appeared; at the end of 1746 it acquired the form of the finished laboratory device.

In Leyden the first to experience the "electric shock" was probably not Musschenbroek himself, but the amateur physicist Andreas Cunaeus, "who entertained himself at home with observing electrical phenomena, with which he had been repeatedly entertained at the home of Musschenbroek... ."[13]

The discovery of the Leyden jar was fully prepared for by the invention of electrifying machines with a conductor (lead) and by experiments on extracting sparks from water. Apparently, therefore, in publishing the Leyden experiment (Ref. 4, p. 208), Musschenbroek is not dealing with his priority, while in the preface cited above he acknowledges with gratitude "the support with wise advice and works of the most noble person Andreas Cunaeus, who ... has agreed to set up the most beautiful experiments, repeat them with me, and bring them to perfection."

To gain the possibility of discharging a Leyden jar without experiencing unhealthy sensations, Musschenbroek used a discharger in the form of a piece of wire (Ref. 4, p. 208). In discussing this question of branched circuits many years later, Henry Cavendish (1731–1810) wrote: "If you discharge a Leyden jar through a short and thick wire that you hold in your hands, then you will not sense an electric shock, since practically all the electricity passes through the wire, rather than through your body."[14]

Musschenbroek compared the "electric shock" from the Leyden jar with the shock of a skate inhabiting the Mediterranean Sea, and advanced the hypothesis of the electrical action of this fish. From that time the term "electric fish" came into use (Ref. 15, p. 637; Ref. 16, p. 96). We find an important remark by Musschenbroek: if one touches the skate with a rod of sealing wax, there will be no effect; yet if one touches the skate with a metallic rod one senses a shock; the shock is sensed both in water and in air (if one takes the skate from the water for a short time). Musschenbroek gives no final answer to the question that he posed of whether the electricity of the skate differs from ordinary ("artificial") electricity (Ref. 17, Vol. 1, pp. 392–393). This remained for other investigators to elucidate.

Musschenbroek's path in science was not free from error. Thus the scientist denied the electrical nature of lightning. Here are his erroneous conclusions (Ref. 4, p. 718): "electric glow" is observed only in a vacuum, whereas lightning exists in air; lightning leaves in walls traces of its passage, while electricity does not; lightning melts metals, but electricity allegedly does not melt even the thinnest metal sheet; lightning emits a cracking sound in air, but to get a sound from electricity one needs some object. It is remarkable how the famous professor erred. Had he not observed the spark discharge in air in his laboratory? Why did he not understand that traces in walls and melting of metals are associated only with the quantitative characteristics of the phenomenon? Musschenbroek knew that a discharge, which is often accompanied by a cracking sound, occurs between two or several objects, but he did not guess that lightning is a discharge between clouds or between a cloud and the earth.

Indeed, after the experiments of 1752 ("extraction of sparks from the atmosphere"), performed according to the design of Franklin, first in France, and then by Franklin himself in America, none of the scientists doubted any longer the electrical nature of lightning, and soon Musschenbroek also began to perform similar experiments, which became the cause of the death of the St. Petersburg academician G. V. Rikhman (1711–1753).

In a letter in Latin to Franklin on 15 April 1759, Musschenbroek gave credit to the American investigator, while noting that "no one has discovered deeper secrets of electricity than Franklin." Further, Musschenbroek expressed the hope that Franklin "will continue to do experiments exclusively on his own initiative, thus traveling a path completely different from the path of the Europeans," which will bring further advances (Ref. 18, p. 27).

Musschenbroek's life came at the period when capitalistic relations were being established in Holland, and subsequently also in England. The colonial expansion of these countries was carried out, whereby Holland (in confederation with the provinces forming the territory of present-day Belgium) long was first in colonial acquisitions and international trade, before losing this position to England.

Pieter (Latin Petrus) van Musschenbroek was born 14 March 1692 in Leyden, where his ancestors had fled from Flanders in the second half of the 16th Century, owing to their Reformed faith. His father Jan Josten van Musschenbroek (1660–1707), together with his brother Samuel Josten (1639–1682), was the first specialized maker of scientific instruments in Holland.[18,19] The business was continued by Jan Josten's sons—Pieter and Jan (1687–1748).

Pieter van Musschenbroek studied philosophy, mathematics, and medicine at Leyden University. In 1715 he received the degree of Doctor of Medicine, and in two years, after medical practice, he went to London, where he studied with Newton, whose ideas he accepted with enthusiasm and subsequently helped to propagate. From London he went to Germany. In 1719 he received there the diploma of Doctor of Philosophy and was appointed professor of philosophy and mathematics of Duisburg University. From this time he intensively occupied himself with experimental physics. As a pedagogue Musschenbroek was famous for accompanying his lectures with amazing experiments, while tirelessly inventing them. In 1723 he was invited to Utrecht University. Musschenbroek lived 17 years at Utrecht. There he wrote his famous works, in particular, repeatedly republishing his systematic course of physics in different countries in Latin and in the national languages. The first, Latin edition of the course was published in 1734,[3] while in 1736 the course was published in Dutch and was the first book on physics in the Dutch language (Ref. 20, pp. 90–91).

In 1739 Musschenbroek was offered the Chair of Philosophy at Leyden University. In January 1740 the scientist assumed his new responsibilities (in 1740 M. V. Lomonosov, who had completed his education abroad, stayed in Leyden (Ref. 21, p. 15)). Musschenbroek died in his native city 19 September 1761.

The monarchs of Denmark, England, Prussia (in 1740), and Spain (in 1743) tried to attract Musschenbroek to their countries. In 1744 there was also an invitation from Russia—to the post of Honorary Professor (Academician) of the St. Petersburg Academy of Sciences. But Musschenbroek refused to leave Holland.[22]

Musschenbroek was a foreign member of the Paris, St. Petersburg (from 1754), and Berlin Academies of Science, of the Montpellier Academy of Sciences, and the Royal Society of London.

A study of Musschenbroek on the technique of meteorological observations is printed in the proceedings of the St. Petersburg Academy of Sciences.[23]

The Dutch scientist was acquainted with the studies of his Russian colleagues. In his "Course of Experimental Physics" in discussing lightning phenomena he reports that the "famous Lomonosov" had observed brilliant and huge (three feet long and one inch thick) electric sparks (Ref. 17, Vol. 1, p. 396). Moreover, Musschenbroek refers to the meteorological observations of Lomonosov (Ref. 17, Vol. 3, p. 457). Among the eminent electrophysicists Musschenbroek also cites Rikhman (Ref. 17, Vol. 1, p. 396).

We should note that the Musschenbroek firm was one of the first (from 1720–1721) major suppliers of scientific instruments for the Cabinet of Curiosities of Peter I (Ref. 24, p. 90).

Some words on the portraiture of Musschenbroek. The portrait illustrating this article is a reproduction of the engraving by I. Koubraken from the picture by Jan Maurits Kvinkhard (1688–1772) dated 1738. The engraving was placed on the fly-leaf of the French translation[25] of Musschenbroek's course in physics. In Leningrad this book exists both in the M. E. Saltykov–Schedrin Public Library and in the Library of the Academy of Sciences of the USSR, but the engraving is contained only in the copy at the Library of the Academy of Sciences. In Ref. 20, p. 88, a color reproduction of a picture by H. van der Mey is placed, dated 1784, in which the brothers Jan and Pieter van Musschenbroek are depicted.

In summarizing the contribution of the Dutch scientist to the science of electricity, we note that Musschenbroek:

–drew attention to the difference in electrification of amber and glass; this facilitated the discovery of two types of charge;

–designed experiments on whose basis the Leyden experiment was performed and the Leyden jar was invented;

–created the prototype of the outer plate of the Leyden jar;

–invented the discharger;

–introduced the term "electric fish" and performed one of the first experiments confirming the electric action of the skate;

–facilitated the propagation and development of the science of electricity with his pedagogic activity, publications, and equipment for electrical experiments.

[1)] This transcription [Myussenbruk] most exactly conveys the Dutch pronunciation, which was kindly confirmed by Professor S. van Bree of Leyden University in a letter of 23 February 1988 to the A. S. Popov Central Museum of Communications in Leningrad.

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[2] W. D. Hackman, *Electricity in Eighteenth-Century Holland*, in *Newton's Scientific and Philosophical Legacy*, eds. P. B. Scheurer and G. Debrock, Kluwer Academic Publishers, Dordrecht, 1988 (Archives Internationales d'Histoire des Idées, No. 123), pp. 175–182.

[3] P. van Musschenbroek, *Elementa Physicae Conscripta in Usus Academicos*, S. Luchtmans, Lugduni Batavorum, 1734, 495 pp.

[4] P. van Musschenbroek, *Institutiones Physicae Conscriptae in Usus Academicos*, S. Luchtmans, Lugduni Batavorum, 1748, 744 pp.

[5] D. J. Struik, Musschenbroek Petrus, van, *Dictionary of Scientific Biography*, Ch. C. Gillespie (Ed.-in-Chief), in 16 vols., Scribner, New York, 1979–1980, Vol. 9, pp. 594–597.

[6] P. van Musschenbroek, *De Viribus Magneticis*, Philos. Trans. **33**, 370–377 (1725).

[7] J. L. Heilbron, *Electricity in the 17th and 18th Centuries: A Study of Early Modern Physics*, University of California Press, Berkeley, Los Angeles, 1979.
[8] Ch.-F. de C. Du Fay, *Sur l'Électricité. Histoire de l'Académie*, Paris, 1733, pp. 4–13.
[9] Ch.-F. de C. Du Fay, A letter from...Translated from the French..., Philos. Trans. R. Soc. London **38**, 258–266 (1733/1734).
[10] Ch.-F. de C. Du Fay, *Cinquième Mémoire sur l'Électricité. Histoire de l'Académie...*, Paris, 1734, pp. 341–361.
[11] S. Gray, *Experiments and Observations upon the Light That Is Produced by Communicating Electrical Attraction to Animal or Inanimate Bodies...*, Philos. Trans. R. Soc. London **39**, 16–24 (1735/1736).
[12] A. Gordon, *Phaenomena Electricitatis Exposita*, Nonnius, Erfurt, 1744, 88 pp. + 2 tables.
[13] J.-A. Nollet, *Observations sur Quelques Nouveaux Phénomènes d'Électricité.* Histoire de l'Académie..., Paris, 1746, pp. 1–17, pp. 1–17 (Histoire); pp. 2–23 (Mémoires).
[14] H. Cavendish, *An Account of Some Attempts to Imitate the Effects of the Torpedo by Electricity*, Philos. Trans. R. Soc. London **66**, 196–225 (1776).
[15] J.-R. Sigaud de la Fond, *Précis Historique et Expérimental des Phénomènes Électriques.* Rue et Hôtel Serpente, Paris, 1781, 744 pp. + 9 plates.
[16] G. Albrecht, *Geschichte der Elektrizität*, Hartleben, Wien, Pest, Leipzig, 1885, 336 pp. (Elektro-technische Bibliothek, Vol. 28).
[17] P. van Musschenbroek, *Cours de Physique Expérimentale* (Transl. by. J.-R. Sigaud de la Fond), 3 vols., Guillyn, Paris, 1769.
[18] I. B. Cohen, *Benjamin Franklin's Science*, Harvard University Press, Cambridge, Mass., 1990.
[19] Musschenbroek, *Bibliographisch-literarisches Handwörterbuch zur Geschichte der exacten Wissenschaften*, ed. J. C. Poggendorff, Barth, Leipzig, 1863, 2 vols., pp. 246–247.
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[25] P. van Musschenbroek, *Essai de Physique* (Transl. from the Dutch by P. Massuet), Vol. 1, Luchtmans, Leyden, 1739, 502 pp.

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