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(*b*. ’sHertogenbosch, Netherlands, 26 September 1688; *d*. Leiden, Netherlands, 28 February 1742)

physics, mathematics, philosophy

’sGravesande was the earliest influential exponent of the Newtonian philosophy in continental Europe, his major work being widely read not only there but also in Britain. His family (originally known as Storm van ’sGravesande) was once important in Delft; like his brothers, he was educated at home by a tutor named Tourton, who was able to encourage his natural mathematical gifts. At Leiden University (1704–1707) he studied law, presenting a doctoral dissertation on the crime of suicide. Again like his brothers, ’sGravesande practiced law at The Hague, where he collaborated with Prosper Marchand and others in founding the *Journal littéraire de la Haye* (l713), a periodical of significance for twenty years in the history of science. He contributed several book reviews and some essays that were reprinted by J. N. S. Allamand in his *Oeuvres philosophiques et mathématiques de Mr. G. J. s’Gravesande* (Amsterdam. 1774). The most celebrated of these (in vol. **12** of the *Journal; Oeuvres*;I, 217–252) was his “Essai d’une nouvelle théorie du choc des corps fondée sur l’expérience” (1722), in which, departing from his customary attachment to the English school, ’sGravesande adopted the Huygens-Leibniz concept of *vis viva*, affirming (prop. X) that “La force d’un corps est proportionelle à sa masse multipliée par le quarré de sa vitesse.” For this he was attacked by Samuel Clarke (1728), against whom he defended himself ably.

His association with the English Newtonian philosophers sprang from his appointment as secretary to the Dutch embassy (Wassenaer van Duyvenvoorde and Borsele van den Hooge) sent early in 1715 to congratulate George I on his accession to the English throne. This duty kept ’sGravesande in England for a year. His introduction to English learned society was facilitated by his acquaintance with the three sons of Gilbert Burnet, one of whom, William, proposed ’sGravesande as a fellow of the Royal Society in February 1715; he was elected on 9 June. On 24 March 1715 he was present (with other foreigners) at a demonstration of experiments by J. T. Desaguliers. There is no other mention of his name in the *Journal Book* until, on the brink of returning to The Hague in February 1716, ’sGravesande made a particular offer of his services to the Royal Society. Nevertheless, it is certain that he became acquainted with Newton and other fellows of the society, especially Desaguliers and John Keill, with whom he afterwards corresponded occasionally.

In June 1717, on the recommendation of Wassenaer van Duyvenvoorde, ’sGravesande was called to Leiden as professor of mathematics and astronomy. His inaugural lecture was on the usefulness of mathematics to all the sciences, physics above all (*Oeuvres*, II, 311-328). In 1734 he was additionally named professor of philosophy. By this time Hermann Boerhaave and ’sGravesande were established as the twin luminaries of Leiden, attracting hundreds of foreign students each year. From the outset of his teaching in both physics and astronomy ’sGravesande modeled his lectures on the example of Newton in the *Principia* and *Opticks*, although in later years they incorporated other influences, especially that of Boerhaave. Moreover, he adopted from Keill and Desaguliers the notion of demonstrating to his classes the experimental proof of scientific principles, accumulating an ever larger collection of apparatus, as may be seen from successive editions of his *Physices elementa mathematica, experimentis confirmat. Sive, introductio ad philosopiam Newtonianam* (Leiden, 1720, 1721). The scientific reputation of ’sGravesande is enshrined in this book, which he constantly corrected and amplified in later editions. An “official” English translation prepared by Desaguliers (to whom copies of the Latin original were sent in haste) was also issued in 1720 and 1721, and it passed through six editions. (The booksellers Mears and Woodward printed a rival version under the name of John Keill.) French translations appeared only in 1746 and 1747, but a critical review by L. B. Castel was published in the *Mémoirés de Trévoux* in May and October 1721. The book was at once welcomed by British and a number of German scholars. ’sGravesande also published an abbreviated account for student use, *Philosophiae Newtonianae institutiones* (Leiden, 1723, 1728; and ed. Allamand 1744).

In 1721 and again in 1722 ’sGravesande visited Kassel at the request of the landgrave to examine the secret perpetual-motion machine constructed by Orffyreus; he was unable to detect a fraud or (apparently) to convince himself that such a device is impossible.

In 1727 he published at Leiden, as a text for his mathematical teaching, *Matheseos universalis elementa. Quibus accedunt, specimen commentarii in Arithmeticam universalem Newtonii: ut et de determinanda forma seriei infinitae adsumtae regula nova (Oeuvres, 89–214). This work, translated into Dutch (1728) and English (1752), is of didactic rather than original merit, but it was significant for its invitation to mathematicians to elucidate systematically Newton’s Universal Arithmetick, which ’sGravesande exemplified by his own explanation of two passages from Newton’s book. ’sGravesande found the lighthearted treatment of infinitesimals and the infinite in Bernard de Fontenelle’s, Élémens de la géométrie de l’infini* (Paris, 1727) unacceptable, and he maintained his objections in the *Journal littéraire* against Fontenelle’s rejoinder (1730).

After commencing the teaching of philosophy, 'sGravesande again published a textbook, *Introductio ad philosophiam, metaphysicam et logicam continens* (Leiden. 1736; repro. 1737, 1756, 1765; Venice, 1737, 1748; French ed., Leiden, 1748)—a work creating some odium for its author by its treatment of the question of necessity and free will. It was republished in *Oeuvres* II, 1–215, together with some previously unprinted essays on metaphysics discovered by Allamand.

Apart from his own writings, 'sGravesande was active in promoting the publication at Leiden of the works of his greater countryman Christian Huygens, in *Opera varia* (1724) and *Opera reliqua* (1728), both of which he edited; in republishing the writings of his friend John Keill in 1725, as well as in editing Newton's *Arithmetica universalis* (1732); and in compiling the Dutch publication of the *Mémoirés de l'Académie royale des sciences contenant les ouvrages adoptés...* (The Hague, 1731). Voltaire made a special journey to Leiden in 1736 to secure 'sGravesande's appraisal of his *Élélemens de la philosophie de Newton* (London, 1738), writing afterward warm a appreciation of 'sGravesande's kindness and learning.

Although 'sGravesande was by no means the first semipopular exponent of Newtonian science and the experimental method (having been preceded in England by David Gregory, William Whiston, John Keill, and Desaguliers, among others), his *Mathematical Elements of Physics* was easily the most influential book of its kind, at least before 1750. It was a larger, better-argued, and more philosophical work than most of its predecessors; moreover, it leaned heavily on *Opticks* (including the queries) as well as on the *Principia*. One should therefore distinguish between 'sGravesande's roles as an exponent of Newtonian concepts (the rules of reasoning, the theory of gravitational attraction and its applications in celestial mechanics, theory of matter, theory of light, and so forth) and as an exponent of an empiricist methodology disdaining postulated hypotheses. Indeed, 'sGravesande contributed nothing to the progress of mathematical physics, for which one must look to the work of other contemporaries such as the Bernoullis, Pierre Varignon, and Alexis Clairaut. The strength of his exposition was in his perfection of the method of justifying scientific truths either by self-evidence or by appeal to experimental verification in the manner already begun by Keill and Desaguliers, perfected by him through the design of many new instruments constructed by the instrument maker Jan van Musschenbroek, brother of Pieter. (The extant instruments are preserved in the Rijksmuseum voor de Geschiedenis der Natuurwetenschappen at Leiden.) Yet, 'sGravesande's teaching and his *Elements* were by no means the sole vehicle for the introduction of British empiricism to the Continent, although probably they were the most important. He had been anticipated by Boerhaave (although Boerhaave did not employ didactic experiments) and was paralleled by Pieter van Musschenbroek at Utrecht (from 1730; he jointed 'sGravesande at Leiden in 1739).

Unlike Newton, 'sGravesande commences his *Elements* with a prefatory discussion of metaphysics and epistemology directed against the Cartesians. The task of physics, he writes, is to determine the laws of nature laid down by the Creator and to unfold their regular operation throughout the universe. In thus examining the true works of God, fictitious hypotheses are to be set aside; but philosophers have differed in their methods of determining the laws of nature and the properties of bodies. "I have therefore thought fit," he continues, "to make good the Newtonian Method, which I have followed in this Work." Since the properties of bodies are not to be learned a priori, who can deny that there are in matter properties not known to us nor essential to matter, which flow from "the free Power of God"? How are the laws of nature to be sought and the three Newtonian laws of motion justified? 'sGravesande replies to these questions in a curious argument. First he asserts Newton's first rule of reasoning (Ockham's Razor). Next, distinguishing the truths of pure mathematics, which are verified by internal consistency, ;from those of physics ("mixed mathematics"), which depend on the senses, he argues that the latter are justified by analogy: "We must look up as true, whatever being denied would destroy civil Society, and deprive us of the means of living." This seemingly means that the consequences of induction must be true, for 'sGravesande goes on specifically to declare: "In Physics we are to discover the Laws of Nature by the Phenomena, then by induction prove them to be general Laws; all the rest is to be handled mathematically." The definitions of the scope of natural philosophy and of a law of nature ("…the Rule and Law, according to which God resolved that certain Motions should always, that is, in all Cases, be performed") follow in chapter 1, which is concluded without further discussion by a statement of Newton's three rules of reasoning.

In volume I, 'sGravesande traverses the theory of matter (influences of the queries in *Opticks* are apparent but not marked), elementary mechanics, the five simple machines, Newton's laws of motion, gravity, central forces, hydrostatics and hydraulics, and pneumatics (including a treatment of sound and wave motion). His second volume opens with three chapters on fire, modeled on Boerhaave's ideas rather than Newton's, in whose manifestations he includes electrical phenomena. There follow two books on optics, one on the system of the world, and a final book entitled "The Physical Causes of the Celestial Motions," in which 'sGravesande can explain only that the cause of these motions is the operation of universal gravitation, whose cause is hidden "and cannot be deduced from Laws that are known." All this is treated with the aid of only trivial mathematics but is enriched with extremely numerous experimental illustrations and examples. Newton's ether does not appear, nor his "fits" of easy transmission and reflection, nor the extremely subtle physical speculation of the queries. No doubt the *Elements* owed almost as much of its success to its omissions and simplicity as to its clear and positive treatment of what it did contain. It was, obviously, very different from such later expositions as those of Henry Pemberton and Colin Maclaurin, and in many respects both more stimulating and more original.

BIBLIOGRAPHY

I. Original Works. Besides works mentioned in text, Allamand's *Oeuvres* (vol. I) include 'sGravesande's youthful *Essai de perspective* (Leiden, 1711; English trans., London, 1724) and other minor writings: *Usage de la chambre obscure; Remarques*

sur la construction des machines pneumatiques; Lettre à Mr. Newton sur une machine inventée par Orffyreus; Remarques touchant le mouvement perpétuel; and *Lettres sur I'utilité mathenmtiques*. The philosophical writings are in vol. II.

II. Secondary Literature. All biographies of 'sGravesande are based on the life by his friend Allamand, prefaced to the *Oeuvres*. See also Pierre Brunet, *Les physiciens hollandaise et la méthode expérimentable en France au XVIII^{e} siècle* (Paris, 1926), *passim;* and *L'introduction des théories, de Newton en France au X VIII^{e} siècle; avant 1738* (Paris, 1931), esp. pp. 97–107; I. Bernard Cohen, *Franklin and Newton* (Philadelphia, 1956), esp. pp. 234–243; C. A. Crommelin, *Descriptive Catalogue of the Physical Instruments of the 18th Century, Including the Collection 'sGravesande-Musschenbroek* (Leiden, 1951); P. C. Molhuysen, P. J. Blok, and K. H. Kossman, *Nieuw Nederlandsch biografisch woordenboek*, VI (Leiden, 1924), cols. 623–627; and A. Thackray, *Atoms and Powers* (Cambridge, Mass., 1970), pp. 101–104.

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