Sciences, n.s. **16** (1889), 458–465—and François Folie's comments on Clausius and his family—"R. Clausius. Sa vie, ses travaux et leur portée métaphysique," in *Revue des questions scientifiques,* **27** (1890), 419–487—are of great value, since we know so little about him apart from his scientific writings.

There is no extensive secondary literature on Clausius himself, but helpful treatments of his ideas appear in most general histories of physics and especially in those on the kinetic theory and thermodynamics. Ferdinand Rosenberger devoted considerable space to Clausius in his *Die Geschichte der Physik,* vol. III (Brunswick, 1890), and Charles Brunold reviewed Clausius' concept of entropy in his *L'entropie* (Paris, 1930), pp. 58–105. G. H. Bryan offered a very positive appraisal of Clausius' contribution to mechanical interpretations of the second law of thermodynamics in his article, "Researches Relating to the Connection of the Second Law with Dynamical Principles," in *Report of the British Association for the Advancement of Science* [Cardiff, 1891] (London, 1892).

More recently, Stephen Brush has evaluated Clausius' work in the kinetic theory of gases in two articles: "The Development of the Kinetic Theory of Gases. III. Clausius," in *Annals of Science,* **14** (1958), 185–196; and "Foundations of Statistical Mechanics, 1845–1915," in *Archive for History of Exact Sciences,* **4** (1967), 145–183. Martin J. Klein has given a perceptive and sensitive appraisal of Gibbs's views on Clausius in "Gibbs on Clausius," in *Historical Studies in the Physical Sciences,* **1** (1969), 127–149. For my views on Rankine and Clausius, see "Atomism and Thermodynamics," in *Isis,* **58** (1967), 293–303; and, for a further discussion on Boltzmann and Clausius, "Probability and Thermodynamics," *ibid.,* **60** (1969), 318–330. In my forthcoming article, "Entropy and Dissipation," due to appear in *Historical Studies in the Physical Sciences,* **2,** I discuss at length the relations between Clausius and the British thermodynamic tradition of Thomson, Maxwell, and Tait.

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CLAVASIO. See **Dominic de Clavasio.**

CLAVIUS, CHRISTOPH (*b.* Bamberg, Germany, 1537; *d.* Rome, Italy, 6 February 1612), *mathematics, astronomy.*

Clavius entered the Jesuit order at Rome in 1555 and later studied for a time at the University of Coimbra (Portugal), where he observed the eclipse of the sun on 21 August 1560. He began teaching mathematics at the Collegio Romano in Rome in 1565, while still a student in his third year of theology; and for all but two of the next forty-seven years he was a member of the faculty as professor of mathematics or as scriptor. From October 1595 until the end of 1596, he was stationed in Naples.

In 1574 Clavius published his main work, *The Elements of Euclid.* (With the help of native scholars, Matteo Ricci, between 1603 and 1607, translated into Chinese the first six books of Clavius' *Elements.*) His contemporaries called Clavius "the Euclid of the sixteenth century." The *Elements,* which is not a translation, contains a vast quantity of notes collected from previous commentators and editors, as well as some good criticisms and elucidations of his own. Among other things, Clavius made a new attempt at proving the "postulate of parallels." In his *Elements* of 1557, the French geometer Peletier held that the "angle of contact" was not an angle at all. Clavius was of a different opinion; but Viète, in his *Variorum de rebus mathematicis responsorum* of 1593, ranged himself on the side of Peletier. In a scholion to the twelfth proposition of the ninth book of Euclid, Clavius objects to Cardanus' claim to originality in employing a method that derives a proposition by assuming the contradictory of the proposition to be proved. According to Clavius, Cardanus was anticipated in this method by Euclid and by Theodosius of Bithynia in the twelfth proposition of the first book of his *Sphaericorum.*

As an astronomer, Clavius was a supporter of the Ptolemaic system and an opponent of Copernicus. In his *In Sphaeram Ioannis de Sacro Bosco commentarius* (Rome, 1581) he was apparently the first to accuse Copernicus not only of having presented a physically absurd doctrine but also of having contradicted numerous scriptural passages. The friendship between Clavius and Galileo, according to their correspondence, began when Galileo was twenty-three and remained unimpaired throughout Clavius' life. In a report of April 1611 to Cardinal Bellarmine of the Holy Office, Clavius and his colleagues confirmed Galileo's discoveries, published in the *Sidereus nuncius* (1610), but they did not confirm Galileo's theory.

In his *Epitome arithmeticae practicae* (Rome, 1583), Clavius gave a distinct notation for "fractions of fractional numbers," but he did not use it in the ordinary multiplication of fractions. His $\frac{3}{5} \cdot \frac{4}{7} \cdot$ means $\frac{3}{5}$ of $\frac{4}{7}$. The distinctive feature of this notation is the omission of the fractional line after the first fraction. The dot cannot be considered as the symbol of multiplication. He offered an explanation for finding the lowest common multiple, which before him only Leonardo Fibonacci in his *Liber abaci* (1202) and Tartaglia in his *General trattato di numeri et misure* (1556) had done. In his *Astrolabium* (Rome, 1593) Clavius gives a "tabula sinuum," in which the proportional parts are separated from the integers by dots. However, his real grasp of that notation is open to doubt, and the more so because in his *Algebra* (Rome, 1608) he wrote all decimal fractions in the form of common fractions. Apart from that, his *Algebra* marks the appearance in Italy of the German plus (+) and minus (−) signs and of algebraic symbols used by Stifel. He was one of the very first to use parentheses to express aggregation of terms. As symbol of the unknown quantity, he used the German radix (𝔄). For additional unknowns he used $1A$, $1B$, etc.; for example, he wrote $3𝔄 + 4A, 4B - 3A$ for $3x + 4y, 4z - 3y$. In his *Algebra*, Clavius did not take notice of negative roots, but he recognized that the quadratic $x^2 + c = bx$ may be satisfied by two values of x. His geometrical proof for this statement was one of the best and most complete. The appendix of his commentary on the *Sphaericorum* of Theodosius (Rome, 1586)—containing a treatise on the sine, the tangent, and the secant—and the rules for the solutions of both plane and spherical triangles in the *Astrolabium*, the *Geometria practica* (Rome, 1604), and the *Triangula sphaerica* (Mainz, 1611) comprehend nearly all the contemporary knowledge of trigonometry; in the *Astrolabium*, for example, is his treatment of the so-called prosthaphaeresis method, by which addition and subtraction were substituted for multiplication, as in

$$\sin a \sin b = \frac{1}{2}[\cos(a - b) - \cos(a + b)].$$

In this he also gives a graphic solution of spherical triangles based on the stereographic projection of the sphere.

Mention must also be made of Clavius' improvement of the Julian calendar. Pope Gregory XIII brought together a large number of mathematicians, astronomers, and prelates, who decided upon the adoption of the calendar proposed by Clavius, which was based on Reinhold's *Prussian Tables*. To rectify the errors of the Julian calendar it was agreed to write in the new calendar 15 October immediately after 4 October of the year 1582. The Gregorian calendar met with a great deal of opposition from scientists such as Viète and Scaliger and from the Protestants.

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The best account of Clavius' works and their several editions can be found in C. Sommervogel, *Bibliothèque de la Compagnie de Jésus*, II (Brussels–Paris, 1891). Some information on his life and work can be found in B. Boncompagni, "Lettera di Francesco Barozzi al P. Christoforo Clavio," in *Bollettino di bibliografia e storia delle scienze matematiche e fisiche*, **17** (1884), 831–837; A. von Braunmühl, *Vorlesungen über Geschichte der Trigonometrie*, I (1900), 189–191; F. Cajori, "Early 'Proofs' of the Impossibility of a Fourth Dimension of Space," in *Archivio di storia della scienza*, **7** (1926), 25–28; J. Ginsburg, "On the Early History of the Decimal Point," in *American Mathematical Monthly*, **35** (1928), 347–349; O. Meyer, "Christoph Clavius Bambergensis," in *Fränkisches Land*, **9** (1962), 1–8; J. E. Montucla, *Histoire des mathématiques*, 2nd ed., I (Paris, 1799), 682–687; E. C. Philips, "The Correspondence of Father Christopher Clavius S. I.," in *Archivum historicum Societatis Iesu*, **8** (1939), 193–222; and J. Tropfke, "Zur Geschichte der quadratischen Gleichungen über dreieinhalb Jahrtausend," in *Jahresbericht der Deutschen Mathematikervereinigung*, **44** (1934), 117–119.

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CLAY (CLAIJ), JACOB (*b.* Berkhout, Netherlands, 18 January 1882; *d.* Bilthoven, Netherlands, 31 May 1955), *physics.*

Clay studied physics at Leiden University and was assistant to Kamerlingh Onnes from 1903 to 1907. He received his doctorate in 1908 with the thesis "De galvanische weerstand van metalen en legeeringen bij lage temperaturen" ("The Galvanic Resistance of Metals and Alloys at Low Temperatures"). He taught in a secondary school at Leiden in 1906 and at Delft from 1907 to 1920. At the Delft Technological University he was *privaat-docent* in natural philosophy from 1913. In 1920 he became professor of physics at the Bandung Technological University (now in Indonesia) and in 1929 took the same post at the University of Amsterdam.

With interest in general physics and its teaching Clay combined a predilection for philosophy, starting from Hegel, and on the experimental side, for atmospheric electricity. In Bandung, assisted by his physicist wife and his children, he investigated the then rather new subject of cosmic radiation. On voyages from Indonesia to the Netherlands he discovered the latitude effect, a diminution in the intensity of cosmic radiation in the equatorial regions that is caused by the earth's magnetic field, thus establishing the presence of charged particles in primary cosmic radiation. Against doubts of other investigators he firmly established the latitude effect and, with the aid of pupils, made further investigations after moving to Amsterdam University. In this connection he worked for the improvement of electric measurements of ionization in general.

Clay's straightforward nature and honest diplomacy made him a good executive as director of scientific institutions. Most of his scientific work is published in *Physica* (The Hague).