in the department of the treasury. He retired from that service in 1926, having been awarded the C.B. (1903); K.C.B. (1909); and K.C.V.O. (1916). His academic distinctions were numerous. The University of Oxford conferred an honorary degree on him; the Royal Society elected him a fellow (1912); and he served on the council of the society. He was a fellow of the British Academy and president of the Mathematical Association from 1922 to 1923.

Heath's main interest lay in the study of Greek mathematics, for which his training in classics and mathematics at Cambridge admirably fitted him; he soon became one of the leading authorities on mathematics in antiquity. The wide range of his interest is reflected in the titles of the works he published. His *History of Greek Mathematics* is usually regarded as his most famous contribution. In *The Thirteen Books of Euclid's Elements* he made available those books of the *Elements* that had hitherto been considered unintelligible; in particular his treatment of book X is a masterpiece.

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I. Original Works. Heath's works, including his translations, are *Diophantus of Alexandria: A Study in the History of Greek Algebra* (Cambridge, 1885; rev. ed., 1910); *Apollonius of Perga: A Treatise on the Conic Sections* (Cambridge, 1896; repr., 1961); *The Works of Archimedes* (Cambridge, 1897); *The Thirteen Books of Euclid's Elements* (Cambridge, 1908; 2nd ed., 1925); *Aristarchus of Samos: The Ancient Copernicus* (Oxford, 1913); *A History of Greek Mathematics,* 2 vols. (Oxford, 1921); *A Manual of Greek Mathematics* (Oxford, 1931); *Greek Astronomy* (London–Toronto–New York, 1932); and *Mathematics in Aristotle* (Oxford, 1949), on which he was working at the time of his death.

Heath also made numerous contributions to the *Mathematical Gazette* and the *Encyclopaedia Britannica* and assisted in the preparation of the 9th ed. of the Liddell-Scott Greek lexicon.

II. Secondary Literature. On his life and work, see the obituaries in the London *Times* (18 Mar. 1940); *Proceedings of the British Academy,* **26** (1940); and *Obituary Notices of the Fellows of the Royal Society,* no. 9 (January 1941).

J. F. Scott

HEAVISIDE, OLIVER (*b.* Camden Town, London, England, 18 May 1850; *d.* Paignton, Devonshire, England, 3 February 1925), *physics, electrical engineering.*

Heaviside was the youngest of four sons of Thomas Heaviside, an artist, and Rachel Elizabeth West, whose sister Emma married Charles Wheatstone in 1847. There is no evidence that his famous uncle contributed to the education of Heaviside, who was almost entirely self-taught and who—except for a job in 1870–1874 as a telegraph operator at Newcastle-on-Tyne—lived privately, supported by his brother and later by well-wishers and by a government pension. Despite the lack of a formal education, Heaviside became expert in mathematical physics and played an important role in the development of the electromagnetic theory of James Clerk Maxwell and in its practical applications.

Having engaged in electrical experimentation since his teens, Heaviside published his first technical article when he was twenty-two. In 1873 and 1876 he proposed methods of making duplex telegraphy practical in papers in the *Philosophical Magazine.* A series of papers in *The Electrician* (1885–1887) firmly established his reputation. They were published in a commercial magazine because of the perspicacity of two successive editors, C. H. W. Biggs and A. P. Trotter, the first of whom lost his post partly as a result of his support for Heaviside, whose ideas on long-distance cable transmission were not in accord with the "official" views of W. H. Preece and H. R. Kempe at the General Post Office; their opposition sufficed to keep Heaviside's papers out of the journals of professional societies and to create difficulties for his supporters generally.

Reduced to essentials, the controversy centered on the effect of inductance in long-distance cables: Preece and Kempe held that it should be minimized, whereas Heaviside's theory unexpectedly predicted that additional inductive coils deliberately inserted at intervals would in fact improve the performance. His assertion was later shown to be correct by M. I. Pupin and others, but in a quarrel between a high government official (Preece was later knighted) and a self-educated maverick living in near penury in a Devon village it was not immediately obvious to all concerned that the latter was right. Even after the papers began appearing in *The Electrician,* understanding dawned slowly, for Heaviside's genius led him to make free and original use of mathematical tools not appreciated by even the most sophisticated contemporary—they were sometimes decades ahead of their rigorous elaboration and application to practical problems.

For example, Heaviside recognized the importance of operational calculus to the investigation of transients, anticipating later employment of Laplace and Fourier transforms in electrical engineering by use of a less rigorous system of his own devising. He developed his own form of vector notation, which resembled that proposed by his great American con-

temporary J. W. Gibbs. He was the first to formulate the "telegraphers' equation" for voltage V as a function of distance x, time t, and resistance R,

$$\frac{1}{C}\frac{\partial^2 V}{\partial x^2} = L\frac{\partial^2 V}{\partial t^2} + R\frac{\partial V}{\partial t},$$

where C and L are capacitance and inductance, terms that he coined (along with "impedance" and "leakance," now generally called "conductance"). This equation, whose coefficients could be optimized to produce a distortionless mode of propagation, proved to have wide application in general dynamics.

Heaviside also suggested a new system of electromagnetic units similar to the mks system now in general use and based on a proposal by Giovanni Giorgi. After the spanning of the Atlantic by radio waves in 1901 he predicted the existence of a reflecting ionized region surrounding the earth, which later became known as the Kennelly-Heaviside layer (and is now called the ionosphere), in recognition of a similar proposal made independently and almost simultaneously by A. E. Kennelly of Harvard University. Heaviside was the first to propose the theory of the steady rectilinear motion of an electric charge through the ether and is said to have predicted the increase of mass of a charge moving at great speeds.

Heaviside's fame spread, and he became something of a legend in his own lifetime. As a result of the scientific help he generously extended to all who sought it, his hermitage near Torquay became known as The Inexhaustible Cavity, even though its inhabitant sometimes lacked the money to pay his dues to professional societies. One of these societies, the Institution of Electrical Engineers, solved the problem by electing him an honorary member and, shortly before his death, awarded him its first Faraday Medal. Heaviside was elected Fellow of the Royal Society in 1891 and received an honorary doctorate from the University of Göttingen. He died alone in his seaside cottage, never having married, and is buried at Paignton.

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II. Secondary Literature. A short biography of Heaviside appears in Rollo Appleyard, *Pioneers of Electrical Communication* (London, 1930); Appleyard also contributed the entry in *Dictionary of National Biography 1922–1930,* pp. 412–414. In 1950, at London, the Institution of Electrical Engineers published *The Heaviside Centenary Volume* of articles on his work, illustrated with plates, including portraits. In 1959 the IEE published a monograph by H. J. Josephs, *The Heaviside Papers Found at Paignton in 1957.* These papers, as well as Heaviside's own library, now repose at the IEE's London headquarters. An excellent source of information on the controversy with Preece, although strongly partisan to Heaviside, is E. T. Whittaker, "Oliver Heaviside," in *Bulletin of the Calcutta Mathematical Society,* **20** (1928–1929), 216–220.

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Charles Süsskind

HECATAEUS OF MILETUS (*fl.* late sixth century and early fifth century B.C.), *geography.*

Very little is known about the life of Hecataeus (Ἑκαταῖος), son of Hegesander. He seems to have belonged to the ruling class of Miletus, since Herodotus quotes him as playing a leading role in the political deliberations of the Ionian states at the time of the Ionian Revolt, 499–494 B.C. (Herodotus V. 36, 125–126—Agathemerus calls him a "much-traveled man" [ἀνὴρ πολυπλανής], *Geographiae informatio* I.1).

Hecataeus is important as one of the earliest Greek prose writers (λογοποιοί) and especially as the author of the earliest geographical work (probably accompanied by a map, which may soon have disappeared; it was apparently not known to Eratosthenes—Strabo, *Geography,* I.1.11.). Numerous quotations from the work have been preserved by later writers; its title is given as *Periodos Gēs* (Περίοδος γῆς), simply *Periodos* (see Jacoby in Pauly-Wissowa, *Real-Encyclopädie,* col. 2671), or *Periegesis* (Περιήγησις). Most of the quotations appear in the lexicon of Stephanus of Byzantium (nearly 300 of the 335 geographical fragments listed by Jacoby come from this source—see *Fragmente,* pp. 16–47); but since this lexicon is extant in an abridged form only and Stephanus' concern was mainly with the different forms of proper names found in ancient authors, the extracts from Hecataeus are disappointingly short and give us little more than the names of various peoples, tribes, towns, rivers, mountains, harbors, islands, and so forth mentioned in the *Periegesis.*