tions and Their Applications to Physics (London, 1895; 2nd ed., rev. by T. M. MacRobert), written with A. Gray; *Algebraic Equations*, Cambridge Mathematical Tracts, no. 6 (Cambridge, 1907; 3rd ed., rev. by W. E. H. Berwick); and *Projective Geometry* (London, 1914). The 2nd ed. of R. F. Scott's *Theory of Determinants* (London, 1904) was revised by Mathews.

Most of Mathews' research papers were published in *Proceedings of the London Mathematical Society* and *Messenger of Mathematics*.

II. SECONDARY LITERATURE. See the obituary notices by W. E. H. Berwick, in *Proceedings of the London Mathematical Society*, 2nd ser., **21** (1923), xlvi–l; and A. Gray, in *Mathematical Gazette*, **11** (1922), 133–136.

T. A. A. BROADBENT

MATHIEU, ÉMILE LÉONARD (*b.* Metz, France, 15 May 1835; *d.* Nancy, France, 19 October 1890), *mathematics, mathematical physics.*

Mathieu showed an early aptitude for Latin and Greek at school in Metz; but in his teens he discovered mathematics, and while a student at the École Polytechnique in Paris he passed all the courses in eighteen months. He took his *docteur ès sciences* in March 1859, with a thesis on transitive functions, but had to work as a private tutor until 1869, when he was appointed to a chair of mathematics at Besançon. He moved to Nancy in 1874, where he remained as professor until his death.

Although Mathieu showed great promise in his early years, he never received such normal signs of approbation as a Paris chair or election to the Académie des Sciences. From his late twenties his main efforts were devoted to the then unfashionable continuation of the great French tradition of mathematical physics, and he extended in sophistication the formation and solution of partial differential equations for a wide range of physical problems. Most of his papers in these fields received their definitive form in his projected *Traité de physique mathématique*, the eighth volume of which he had just begun at the time of his death. These volumes and a treatise on analytical dynamics can be taken as the basis for assessing his achievements in applied mathematics, for they contain considered versions, and often extensions, of the results that he had first published in his research papers. Mathieu's first major investigation (in the early 1860's) was an examination of the surfaces of vibration that arise as disturbances from Fresnel waves by considering the dispersive properties of light. His later interest in the polarization of light led him to rework a number of problems in view of certain disclosed weaknesses in Cauchy's analyses.

One of Mathieu's main interests was in potential theory, in which he introduced a new distinction between first and second potential. "First potential" was the standard idea, defined, for example, at a point for a body V by an expression of the form

$$\int_V \frac{1}{r} f(x, y, z)\, dv; \qquad (1)$$

but Mathieu also considered the "second potential"

$$\int_V r f(x, y, z)\, dv, \qquad (2)$$

the properties of which he found especially useful in solving the fourth-order partial differential equation

$$\nabla^2 \nabla^2 w = 0. \qquad (3)$$

His interest in (3) arose especially in problems of elasticity; and in relating and comparing his solutions with problems in heat diffusion (where he had investigated various special distributions in cylindrical bodies), he was led to generalized solutions for partial differential equations and to solutions for problems of the elasticity of three-dimensional bodies, especially those of anisotropic elasticity or subject to noninfinitesimal deformations. Mathieu applied these results to the especially difficult problem of the vibration of bells, and he also made general applications of his ideas of potential theory to the study of dielectrics and magnetic induction. In his treatment of electrodynamics he suggested that the traversal of a conductor by an electric current gave rise to a pair of neighboring layers of electricity, rather than just a single layer.

Mathieu introduced many new ideas in the study of capillarity, improving upon Poisson's results concerning the change of density in a fluid at its edges. His most notable achievement in this field was to analyze the capillary forces acting on an arbitrary body immersed in a liquid, but in general his results proved to be at variance with experimental findings.

In celestial mechanics Mathieu extended Poisson's results on the secular variation of the great axes of the orbits of planets and on the formulas for their perturbation; he also analyzed the motion of the axes of rotation of the earth and produced estimates of the variation in latitude of a point on the earth. Mathieu studied the three-body problem and applied his results to the calculation of the perturbations of Jupiter and Saturn. In analytical mechanics, he gave new demonstrations of the Hamiltonian systems of equations and of the principle of least action, as well as carrying out many analyses of compound motion, especially those that took into account the motion of the earth.

In all his work Mathieu built principally on solution methods introduced by Fourier and problems investigated by Poisson, Cauchy, and Lamé. The best-known of his achievements, directly linked with his name, are the "Mathieu functions," which arise in solving the two-dimensional wave equation for the motion of an elliptic membrane. After separation of the variables, both space variables satisfy an ordinary differential equation sometimes known as Mathieu's equation:

$$\frac{d^2u}{dz^2} + (a + 16b \cos 2z)u = 0, \qquad (4)$$

whose solutions are the Mathieu functions $ce_n(z, b)$, $se_n(z, b)$. These functions are usually expressed as trigonometric series in z, each of which takes an infinite power series coefficient in b; but many of their properties, including orthogonality, can be developed from (4) and from various implicit forms. Both equation (4) and the functions were an important source of problems for analysis from Mathieu's initial paper of 1868 until the second decade of the twentieth century. The functions themselves are a special case of the hypergeometric function, and Mathieu's contributions to pure mathematics included a paper on that function. He also wrote on elliptic functions and especially on various questions concerned with or involving higher algebra—the theory of substitutions and transitive functions (his earliest work, and based on extensions to the results of his thesis) and biquadratic residues. In fact, his earliest work was in pure mathematics; not until his thirties did applied mathematics assume a dominant role in his thought.

Mathieu's shy and retiring nature may have accounted to some extent for the lack of worldly success in his life and career; but among his colleagues he won only friendship and respect. Apart from a serious illness in his twenty-eighth year, which seems to have prevented him from taking over Lamé's lecture courses at the Sorbonne in 1866, he enjoyed good health until the illness that caused his death.

BIBLIOGRAPHY

I. Original Works. The 7 vols. of Mathieu's *Traité de physique mathématique* were published at Paris: *Cours de physique mathématique* (1874); *Théorie de la capillarité* (1883); *Théorie du potentiel et ses applications à l'électrostatique et au magnetisme*, 2 vols. (1885–1886), also trans. into German (1890); *Théorie de l'électrodynamique* (1888); and *Théorie de l'élasticité des corps solides*, 2 vols. (1890). The 3 vols. that were still projected at his death were to have dealt with optics, the theory of gases, and acoustics. His other book was *Dynamique analytique* (Paris, 1878). His papers were published mostly in *Journal de physique*, *Journal für die reine und angewandte Mathematik*, and especially in *Journal des mathématiques pures et appliquées*. A comprehensive list of references can be found in Poggendorff, IV, 1972.

II. Secondary Literature. The two principal writings are P. Duhem, "Émile Mathieu, His Life and Works," in *Bulletin of the New York Mathematical Society*, **1** (1891–1892), 156–168, translated by A. Ziwet; and G. Floquet, "Émile Mathieu," in *Bulletin . . . de la Société des sciences de Nancy*, 2nd ser., **11** (1891), 1–34. A good treatment of Mathieu's equation and functions may be found in E. T. Whittaker and G. N. Watson, *A Course of Modern Analysis* (Cambridge, 1928), ch. 19.

I. Grattan-Guinness

MATHURĀNĀTHA ŚARMAN (*fl.* Bengal, India, 1609), *astronomy.*

Mathurānātha, who enjoyed the titles Vidyālaṅkāra ("Ornament of Wisdom") and Cakravartin ("Emperor"), composed the *Ravisiddhāntamañjarī* in 1609. This is an astronomical text in four chapters accompanied by extensive tables (see Supplement) based on the parameters of the *Saurapakṣa* with the admixture of some from the adjusted *Saurapakṣa*; the epoch is 29 March 1609. His is one of the primary sets of tables belonging to this school in Bengal. Another set of tables, the *Viśvahita*, is sometimes attributed to him, but its author is, rather, Rāghavānanda Śarman. Mathurānātha also wrote a *Praśnaratnāṅkura* and a *Pañcāṅgaratna*, but little is known of either.

BIBLIOGRAPHY

The *Ravisiddhāntamañjarī* was edited by Viśvambhara Jyotiṣārṇava as *Bibliotheca Indica*, no. 198 (Calcutta, 1911); the tables are analyzed by D. Pingree, *Sanskrit Astronomical Tables in England* (Madras, 1973), 128–134.

David Pingree

MATRUCHOT, LOUIS (*b.* Verrey-sous-Salmasse, near Dijon, France, 14 January 1863; *d.* Paris, France, 5 July 1921), *mycology.*

Matruchot was admitted to the École Normale Supérieure in 1885. After passing the *agrégation* he became assistant science librarian there in 1888. In 1901 he was named lecturer in botany at the Sorbonne, where he also held a professorship in mycology. He