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(*b*, St. Gall, Switzerland, 12 June 1577; *d*. Graz, Austria, 3 November 1643)

mathematics.

Guldin was of Jewish descent but was brought up as a Protestant. He began work as a goldsmith and as such was employed in several German towns. At the age of twenty he was converted to Catholicism and entered the Jesuit order, changing his first name, Habakkuk, to Paul. In 1609 he was sent to Rome for further education. Guldin taught mathematics at the Jesuit colleges in Rome and Graz. When a severe illness obliged him to suspend his lecturing, he was sent to Vienna, where he became professor of mathematics at the university. In 1637 he returned to Graz, where he died in 1643.

In 1582 the Gregorian calendar was introduced in western Europe, and it met with a great deal of opposition among both scientists and Protestants; one of the opponents was the famous chronologist Sethus Calvisius. To refute him and to defend Pope Gregory XIII and his fellow Jesuit Christoph Clavius, Guldin published his first work, *Refutatio elenchi calendarii Gregoriani a Setho Calvisio conscripti* (Mainz, 1618).

In 1622 Guldin published a physicomathematical dissertation on the motion of the earth caused by alteration of the center of gravity. In it he made the assumption that every unimpeded large body whose center of gravity does not coincide with the center of the universe is moved in such a way that it will coincide with the latter. In the fourteenth century the doctrine of centers of gravity had begun to play a role in the mechanics of large bodies. In his *Quaestiones super libros quattuor de caelo et mundo Aristotelis*, Jean Buridan argued that geological processes are always causing a redistribution of the earth's matter and therefore are continually changing its center of gravity. But the center of gravity always strives to be at the center of the universe, so the earth is constantly shifting about near the latter. Guldin accepted Buridan's hypothesis but was also well-informed about the objection which Nicole Oresme had formulated in his *Le livre du ciel et du monde*.

In 1627 a correspondence on religious subjects developed between Guldin and Johannes Kepler. On the occasion of his journey from Ulm to Prague, which he undertook to solicit funds from Emperor Rudolph II for the publication of the Rudolphine Tables (Ulm, 1627), Kepler wrote on his objections to the Catholic religion to Guldin. In his answer Guldin tried to refute them with theological arguments drawn up for him by a fellow Jesuit. Kepler's reply ended the correspondence.

Guldin's main work was *Centrobaryca seu de centro gravitatis trium specierum quantitatis continuae*, in four volumes (Vienna, 1635-1641). In the first volume Guldin determined the centers of gravity of plane rectilinear and curvilinear figures and of solids in the Archimedean manner. Against Niccolò Cabeo's attacks in *Philosophia magnetica* (1629) directed toward his theory concerning the motion of the earth, Guldin reproduced in volume I his dissertation of 1622 and a note in which he discussed Cabeo's arguments. The appendix to volume I contains tables of quadratic and cubic numbers and an exposition of the use of logarithms referring to Adriaan Vlacq's *Arithmetica logarithmica* (1628).

Volume II contains what is known as Guldin's theorem: "If any plane figure revolve about an external axis in its plane, the volume of the solid so generated is equal to the product of the area of the figure and the distance traveled by the center of gravity of the figure" (ch. 7, prop. 3, p. 147). This theorem has been much discussed in terms of possible plagiarism from the early part of book VII of Pappus' *Collectio* (*ca*. A.D. 300). However, the theorem cannot have been taken from the first published edition of the *Collectio*, the Latin translation of Federico Commandino (Venice, 1588), because that text shows obvious lacunae. Guldin attempted to prove his theorem by metaphysical reasoning, but Bonaventura Cavalieri pointed out the weakness of his demonstration and proved the theorem by the method of indivisibles. Volume II treats the properties of the Archimedean spiral and the conic sections, their lengths and surfaces, the determination of the center of gravity of a sector of a circle and of a segment of a circle and a parabola, the rise of solids of revolution, and the application of the Guldin theorem to them.

In volume III Guldin determined the surface and the volume of a cone, a cylinder, a sphere, and other solids of revolution and their mutual proportions. In his *Stereometria doliorum* (1615) Kepler determined the volumes of certain vessels and the areas of certain surfaces by means of infinitesimals, instead of the long and tedious method of exhaustions. In volume IV Guldin severely attacked Kepler for the lack of rigor in his use of infinitesimals. He also criticized Cavalieri's use of indivisibles in his *Geometria indivisibilibus* (1635), asserting not only that the method had been taken from Kepler but also that since the number of indivisibles was infinite, they could not be compared with one another. Furthermore, he pointed out a number of fallacies to which the method of indivisibles appeared to lead.

In 1647, after the death of Guldin, Cavalieri published *Exercitationes geometricae sex*, in which he defended himself against the first charge by pointing out that his method differed from that of Kepler in that it made use only of indivisibles, and against the second by observing that the two infinities of elements to be compared are of the same kind.

BIBLIOGRAPHY

Guldin's writings are listed in the text. A very good account of his works may be found in C. Sommervogel, *Bibliothèque de la Compagnie de Jésus*, II (Brussels-Paris, 1891), 1946-1947.

On Guldin or his work, see the following (listed chronologically): C. J. Gerhardt, *Geschichte der Mathematik in Deutschland* (Munich, 1877), pp. 129-130; L. Schuster, *Johann Kepler und die grossen kirchlichen Streitfragen seiner Zeit* (Graz, 1888), pp. 217-228, 233-243; M. Cantor, *Vorlesungen über Geschichte der Mathematik*, II (Leipzig, 1900), 840-844; H. G. Zeuthen, *Geschichte der Mathematik im 16. und 17. Jahrhundert* (Leipzig, 1903), pp. 240, 241, 293; G. A. Miller, "Was Paul Guldin a Plagiarist?," in *Science*, **64** (1926), 204-206; P. Ver Eecke, "Le théorèmedit de Guldin considéré au point de vue historique," in *Mathésis*, **46** (1932), 395-397; R. C. Archibald, "Notes and Queries," in *Scripta mathematica*,**1** (1932), 267; P. Duhem, *Le système du monde*, IX (Paris, 1958), 318-321; C. B. Boyer, *The History of the Calculus and Its Conceptual Development* (New York, 1959), pp. 121, 122, 138, 139; and J. E. Hofmann, "Ueber die *Exercitatio geometrica* des M. A. Ricci," in *Centaurus*, **9** (1963), 151, 152.

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