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(*b*. Milan, Italy, 1647 or 1648; *d*. Mantua, Italy, 1734),

mathematics.

Ceva's dates must be inferred from incomplete information; he died sometime in 1734 at the age of eighty-six years and six months and therefore must have been born in 1647 or 1648. In his correspondence with Antonio Magliabecchi, the librarian of the grand duke of Tuscany, Ceva states that he studied in Pisa, and in the preface to one of his books he gives particular praise to Donato Rossetti, who was a professor of logic there until he moved to Turin in 1674, He further mentions Alessandro Marchetti (1633– 1714) and his son Angiolo Marchetti (1674–1753), both professors of mathematics at Pisa. Ceva was married and a daughter was born to him on 28 October 1685. His father was still living with him in Mantua in 1686. His brother was the poet, philosopher, and mathematician Tommaso Ceva. The bishop of Tortona, Carlo Francesco Ceva, was his cousin.

Ceva described his youth as saddened by "many kinds of misfortune" and his later work as distracted by "serious cares and affairs of his friends and family." At the time of his death his name was carried in a register of the salaried employees of the royal court as "Commissario dell'arciducale Camera et Matematico cesareo." He was buried in the church of St. Teresa de' Carmelitani Scalzi.

Ceva's efforts concerning the problem of diverting the river Reno into the Po deserve special attention; his opposition to this plan of the Bolognese led to the abandonment of the project.

Ceva's most important mathematical work is *De lineis rectis* (Milan, 1678), dedicated to Ferdinando Carlo. Chasles mentions it with praise in his *Aperçu historique*. In this work Ceva used the properties of the center of gravity of a system of points to obtain the relation of the segments which are produced by straight lines drawn through their intersections. He further utilized these properties in many theorems of the theory of transverse lines—for example, in placing at the points of intersection of the straight lines weights that are inversely proportional to the segments. From the relations of the weights, which are determined by the law of the lever, the relation of the segments is then derived. Ceva first applied his method, which is a combination of geometry and mechanics, to five basic figures, which he called "elements." He then used these in special problems, in which given relations are used to calculate others. The theorem of Menelaus concerning the segments produced by a transverse line of a triangle is proved, as is the transversal theorem concerning the concurrency of the transverse lines through the vertices of a triangle, which is named after Ceva. This theorem was established again by Johann I Bernoulli. Ceva worked with proportions and proved their expansion; he calculated many examples in detail and for all possible cases. (Occasionally he treated examples in a purely geometrical manner to demonstrate the advantage of his method.)

In the second book of the *De lineis*, Ceva went on to more complex examples and applied his method to cylindrical sections, ellipses in the triangle, and conic sections and their tangents.

In a geometrical supplement, not related to either of the first two books, Ceva dealt with classical geometrical theorems. He solved problems on plane figures bounded by arcs of circles and then calculated the volumes and centers of gravity of solid bodies, such as the paraboloid and the two hyperboloids of rotation. Cavalieri's indivisibles are used successfully in this case.

Ceva's mastery of all the other geometrical problems of his time is shown by other works which are dedicated to the mathematician Cardinal Ricci. Among these, the *Opuscula mathematica* (Milan, 1682) met with particular acclaim.

The *Opuscula* is in four parts. In the first part Ceva investigated forces and formed the parallelogram of forces and the resultants of many different forces. Geometrical proofs accompany the mechanical considerations. "Geometrical proofs can themselves provide a verification for that which we have determined mechanically," Ceva wrote in the scholium to the sixth proposition. He then considered levers at greater length and obtained proportions for the quadrangle by means of lever laws. He further discussed centers of gravity for surfaces and bodies. In all the problems he showed how geometry can be used profitably in statics.

In the second part of the book, Ceva investigated pendulum laws—here he refers to Galileo. In the third proposition of this section, Ceva arrived at the erroneous conclusion (which he later corrected) that the periods of oscillation of two pendulums are in the ratio of their lengths.

Solid bodies and perforated vessels are observed in flowing water in the last part of the work. Flow velocity is measured by means of the motion of pendulums suspended in the flow. Finally the amount of water is measured by means of flow cross sections. In the last pages, Ceva again added a geometrical appendix. He examined a ring with a semicircular cross section and proved that certain sections cannot be elliptical. He then calculated the center of gravity of the surface of a hemisphere by using Cavalieri's indivisibles and indicated that it is not necessary to work with parallel sections in this method. Central sections, "small cones," could also be used in the calculation. Ceva's infinitesimal method is sketched in this section with clear and detailed demonstrations.

A third work, *Geometria motus* (Bologna, 1692), is also of great interest. Here Ceva attempted to determine the nature of motions geometrically, stating that he has always been "interested without restraint" in such studies. His further prefatory remark—that geometry brings unadulterated truth—again indicated his interest in pure geometry. Ceva worked with coordinate systems.

$s = f(v)$; $s = f(t)$, etc.

The areas defined by the curves are determined by the Cavalieri method. Although he preferred the geometrical method, he did not hesitate to use indivisibles and he considered the points of curves to be quantities "smaller than any of those specified." After he had examined individual motions, he went on to a comparison of motions. This brought him to parabolas and hyperbolas, and he made particular reference to the work of Stephano de Angelis (*Miscellaneum hyperbolicum et parabolam*, Venice, 1659). Ceva assumed that, over an "infinitely short distance," motion can be considered uniform. He gave no more precise substantiation of this view, however.

Ceva treated composite motions in the second book of the *Geometria motus*. Here he also discussed the laws of pendulums and (in the scholium on the fifteenth proposition, theorem XI) corrected his error in the *Opuscula mathematica*. In considering motions of points along curves, Ceva was led to a comparison between parabolas and spirals with equal arcs. He considered the lines as "flows of points." He also investigated bodies formed by the rotation of certain figures and considered the falling of bodies along inclined planes, the subject of a great deal of his previous work. The final part of the *Geometria* consists of studies on the stretching and motion of ropes in which weights suspended by ropes are experimentally raised and dropped.

Although Ceva used archaic and complicated formulations, the *Geometria* anticipates or at least suggests elements of infinitesimal calculus.

Ceva's interest in a variety of problems led him to produce *De re numeraria* (Mantua, 1711), a work praised by Cinelli for its great accuracy.

Ceva frequently became involved in controversies on physical problems. In particular he criticized Paster Vanni's erroneous conception of the distribution of forces on an inclined plane.

BIBLIOGRAPHY

I. Original Works. Ceva's extant writings include *De lineis rectis se invicem secantibus statica constructio* (Milan, 1678); *Opuscula mathematica* (Milan, 1682); *Geometria motus* (Bologna, 1692); *Tria problemata geometrice proposita (Mantua, 1710); De re numeraria, quod fieri potuit, geometrice tractata* Mantua. 1711); *De mundi fabrica, una gravitatis principio innixo* (Mantua, 1715); his polemical works concerning the diversion of the Reno into the Po, *Le conseguenze del Reno, se con l'aderire al progretto de' Signori Bolognesi si permetesse in Po grande* (Mantua, 1716; Bologna, 1716), *Replica de Giovanni Ceva indifesa delle sue dimostrazioni, e ragioni, per quali non debassi introdurre Reno in Po, contro la riposta data dal Sig. Eustachio Manfredi* (Mantua, 1721), and *Riposta de Giovanni Ceva alle osservazioni dal Signor dottor Eustachio Manfredi contro la di lui replica in proposito dell'immissione de Reno in Po grande pretesa da' Signori Bolognesi* (Mantua, 1721); *Hydrostatica* (Mantua, 1728); and two letters, one addressed to Vincenzo Viviani and the other to Antonio Magliabecchi, in the Royal Library in Florence.

II. Secondary Literature. See Gino Loria, "Per la biografia de Giovanni Ceva," in *Rendiconti dell'istituto lombardo di scienze e lettere*, **48** (1915), 450–452.

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