Augustin-Louis Cauchy (1789 – 1857)

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Baron Augustin-Louis Cauchy was a French mathematician who was an early pioneer of analysis. He started the project of formulating and proving the theorems of infinitesimal calculus in a rigorous manner, rejecting the heuristic principle of the generality of algebra exploited by earlier authors. He defined continuity in terms of infinitesimals and gave several important theorems in complex analysis and initiated the study of permutation groups in abstract algebra. A profound mathematician, Cauchy exercised a great influence over his contemporaries and successors. His writings cover the entire range of mathematics and mathematical physics.

Cauchy was a prolific writer; he wrote approximately eight hundred research articles and five complete textbooks. He was a devout Roman Catholic, strict Bourbon royalist, and a close associate of the Jesuit order.

Youth and education:

Cauchy was the son of Louis François Cauchy (1760-1848) and Marie-Madeleine Desestre. Cauchy had two brothers, Alexandre Laurent Cauchy (1792-1857), who became a president of a division of the court of appeal in 1847, and a judge of the court of cassation in 1849; and Eugene Francois Cauchy (1802-1877), a publicist who also wrote several mathematical works.

Cauchy married Aloise de Bure in 1818. She was a close relative of the publisher who published most of Cauchy's works. By her he had two daughters, Marie Françoise Alicia (1819) and Marie Mathilde (1823).

Cauchy's father (Louis François Cauchy) was a high official in the Parisian Police of the New Régime. He lost his position because of the French Revolution (July 14, 1789) that broke out one month before Augustin-Louis was born. The Cauchy family survived the revolution and the following Reign of Terror (1794) by escaping to Arcueil, where Cauchy received his first education, from his father. After the execution of Robespierre (1794), it was safe for the family to return to Paris. There Louis-François Cauchy found himself a new bureaucratic job, and quickly moved up the ranks. When Napoleon Bonaparte came to power (1799), Louis-François Cauchy was further promoted, and became Secretary-General of the Senate, working directly under Laplace (who is now better known for his work on mathematical physics). The famous mathematician Lagrange was also no stranger in the Cauchy family.

On Lagrange's advice, Augustin-Louis was enrolled in the École Centrale du Panthéon, the best secondary school of Paris at that time, in the fall of 1802. Most of the curriculum consisted of classical languages; the young and ambitious Cauchy, being a brilliant student, won many prizes in Latin and Humanities. In spite of these successes, Augustin-Louis chose an engineering career, and prepared himself for the entrance examination to the École Polytechnique.

In 1805 he placed second out of 293 applicants on this exam, and he was admitted. One of the main purposes of this school was to give future civil and military engineers a high-level scientific and mathematical education. The school functioned under military discipline, which caused the young and pious Cauchy some problems in adapting. Nevertheless, he finished the Polytechnique in 1807, at the age of 18, and went on to the École des Ponts et Chaussées (School for Bridges and Roads). He graduated in civil engineering, with the highest honors.

Engineering days:

After finishing school in 1810, Cauchy accepted a job as a junior engineer in Cherbourg, where Napoleon intended to build a naval base. Here Augustin-Louis stayed for three years, and although he had an extremely busy managerial job, he still found time to prepare three mathematical manuscripts, which he submitted to the Première Classe (First Class) of the Institut de France. Cauchy's first two manuscripts (on polyhedra) were accepted; the third one (on directrices of conic sections) was rejected.

In September 1812, now 23 years old, after becoming ill from overwork, Cauchy returned to Paris. Another reason for his return to the capital was that he was losing his interest in his engineering job, being more and more attracted to abstract beauty of mathematics; in Paris he would have a much better chance to find a mathematics related position. Although he formally kept his engineering position, he was transferred from the payroll of the Ministry of the Marine to the Ministry of the Interior. The next three years Augustin-Louis was mainly on unpaid sick leave, and spent his time quite fruitfully, working on mathematics (on the related topics of symmetric functions, the symmetric group and the theory of higher-order algebraic equations). He attempted admission to the First Class of the Institut de France but failed on three different occasions between 1813 and 1815. In 1815 Napoleon was defeated at Waterloo, and the newly installed Bourbon king Louis XVIII (a brother of the beheaded Louis XVI) took the restoration in hand. The Académie des Sciences was re-established in March 1816; Lazare Carnot and Gaspard Monge were removed from this Academy for political reasons, and the king appointed Cauchy to take the place of one of them. The reaction by Cauchy's peers was harsh; they considered his acceptance of membership of the Academy an outrage, and Cauchy thereby created many enemies in scientific circles.

Professor at École Polytechnique:

In November 1815, Louis Poinsot, who was an associate professor at the École Polytechnique, asked to be exempted from his teaching duties for health reasons. Cauchy was by then a rising mathematical star, who certainly merited a professorship. One of his great successes at that time was the proof of Fermat's polygonal number theorem. However, the fact that Cauchy was known to be very loyal to the Bourbons, doubtless also helped him in becoming the successor of Poinsot. He finally quit his engineering job, and received a one-year contract for teaching mathematics to second-year students of the École Polytechnique. In 1816, this Bonapartist, non-religious school was reorganized, and several liberal professors were fired; the reactionary Cauchy was promoted to full professor.

When Cauchy was 28 years old, he was still living with his parents. His father found it high time for his son to marry; he found him a suitable bride, Aloïse de Bure, five years his junior. She was a close relative of the publisher who published most of Cauchy's works. They were married on April 4, 1818, with great Roman Catholic pomp and ceremony, in the Church of Saint-Sulpice. In 1819 the couple's first daughter, Marie Françoise Alicia, was born, and in 1823 the second and last daughter, Marie Mathilde. Cauchy had two brothers: Alexandre Laurent Cauchy, who became a president of a division of the court of appeal in 1847, and a judge of the court of cassation in 1849; and Eugène François Cauchy, a publicist who also wrote several mathematical works.

The oppressive political climate that lasted until 1830 suited Cauchy perfectly. In 1824 Louis XVIII died, and was succeeded by his even more reactionary brother Charles X. During these years Cauchy was highly productive, and published one important mathematical treatise after another. He received cross appointments at the Collège de France, and the Faculté des Sciences of the University.

Last years:

Cauchy returned to Paris and his position at the Academy of Sciences late in 1838. He could not regain his teaching positions, because he still refused to swear an oath of allegiance. However, he desperately wanted to regain a formal position in Parisian science.

In August 1839 a vacancy appeared in the Bureau des Longitudes. This Bureau had some resemblance to the Academy; for instance, it had the right to co-opt its members. Further, it was believed that members of the Bureau could "forget" about the oath of allegiance, although formally, unlike the Academicians, they were obliged to take it. The Bureau des Longitudes was an organization founded in 1795 to solve the problem of determining position on sea - mainly the longitudinal coordinate, since latitude is easily determined from the position of the sun. Since it was thought that position on sea was best determined by astronomical observations, the Bureau had developed into an organization resembling an academy of astronomical sciences.

In November 1839 Cauchy was elected to the Bureau, and discovered immediately that the matter of the oath was not so easily dispensed with. Without his oath, the king refused to approve his election. For four years Cauchy was in the absurd position of being elected, but not being approved; hence, he was not a formal member of the Bureau, did not receive payment, could not participate in meetings, and could not submit papers. Still Cauchy refused to take any oaths; however, he did feel loyal enough to direct his research to celestial mechanics. In 1840, he presented a dozen papers on this topic to the Academy. The confounded membership of the Bureau lasted until the end of 1843, when Cauchy was finally replaced by Poinsot.

All through the nineteenth century the French educational system struggled with the separation of Church and State. The Catholic Church strived for freedom of education (that is, the right to establish Catholic schools); the Church found in Cauchy a staunch and illustrious ally in this struggle. He lent his prestige and knowledge to the École Normale Écclésiastique, a school in Paris run by Jesuits, for training teachers for their colleges. He also took part in the founding of the Institut Catholique. The purpose of this institute was to counter the effects of the absence of Catholic university education in France. These activities did not make Cauchy popular with his colleagues who, on the whole, supported the Enlightenment ideals of the French Revolution. When a chair of mathematics became vacant at the Collège de France in 1843, Cauchy applied for it, but got just three out of 45 votes.

The year 1848 was the year of revolution all over Europe; revolutions broke out in numerous countries, beginning in France. King Louis-Philippe, fearful of sharing the fate of Louis XVI, fled to England. The oath of allegiance was abolished, and the road to an academic appointment was finally clear for Cauchy. On March 1, 1849, he was reinstated at the Faculté de Sciences, as a professor of mathematical astronomy. After political turmoil all through 1848, France chose to become a Republic, under the Presidency of Louis Napoleon Bonaparte, nephew of Napoleon Bonaparte, and son of Napoleon's brother, who had been installed as the first king of Holland. Soon (early 1852) the President became the Emperor of France, and took the name Napoleon III.

Not unexpectedly, the idea came up in bureaucratic circles that it would be useful to require a loyalty oath from all state functionaries, including university professors. Not always does history repeat itself, however, because this time a cabinet minister was able to convince the Emperor to exempt Cauchy from the oath. Cauchy remained a professor at the University until his death at the age of 67. He received the Last Sacraments and died at 4 a.m. during the night of May 23, 1857.

His name is one of the 72 names inscribed on the Eiffel Tower.

Wave theory, mechanics, elasticity, etc.:

In the theory of light he worked on Fresnel's wave theory and on the dispersion and polarization of light. He also contributed significant research in mechanics, substituting the notion of the continuity of geometrical displacements for the principle of the continuity of matter. He wrote on the equilibrium of rods and elastic membranes and on waves in elastic media. He introduced a 3 x 3 symmetric matrix of numbers that is now known as the Cauchy stress tensor. In elasticity, he originated the theory of stress, and his results are nearly as valuable as those of Simeon Poisson. Other significant contributions include being the first to prove the Fermat polygonal number theorem.

Cauchy is most famous for his single-handed development of complex function theory.

He was the first to prove Taylor's theorem rigorously, establishing his well-known form of the remainder. He wrote a textbook for his students at the École Polytechnique in which he developed the basic theorems of mathematical analysis as rigorously as possible. In this book he gave the necessary and sufficient condition for the existence of a limit in the form that is still taught. Also Cauchy's well-known test for absolute convergence stems from this book: Cauchy condensation test. In 1829 he defined for the first time a complex function of a complex variable in another textbook. In spite of these, Cauchy's own research papers often used intuitive, not rigorous, methods; thus one of his theorems was exposed to a "counter-example" by Abel, later fixed by the introduction of the notion of uniform continuity.

In a paper published in 1855, two years before Cauchy's death, he discussed some theorems, one of which is similar to the "Argument Principle" in many modern textbooks on complex analysis. In modern control theory textbooks, the Cauchy argument principle is quite frequently used to derive the Nyquist stability criterion, which can be used to predict the stability of negative feedback amplifier and negative feedback control systems. Thus Cauchy's work has a strong impact on both pure mathematics and practical engineering.

Output:

Cauchy was very productive, in number of papers second only to Leonhard Euler. It took almost a century to collect all his writings into 27 large volumes:

Oeuvres complètes d'Augustin Cauchy publiées sous la direction scientifique de l'Académie des sciences et sous les auspices de M. le ministre de l'Instruction publique (27 volumes) (Paris : Gauthier-Villars et fils, 1882–1974)

His greatest contributions to mathematical science are enveloped in the rigorous methods which he introduced; these are mainly embodied in his three great treatises:

Cours d'analyse de l'École royale polytechnique (1821)
Le Calcul infinitésimal (1823)
Leçons sur les applications de calcul infinitésimal; La géométrie (1826–1828)

His other works include:

Exercices d'analyse et de physique mathematique (Volume 1)
Exercices d'analyse et de physique mathematique (Volume 2)
Exercices d'analyse et de physique mathematique (Volume 3)

Exercices d'analyse et de physique mathematique (Volume 4) (Paris: Bachelier, 1840–1847)
Analyse algèbrique (Imprimerie Royale, 1821)
Nouveaux exercices de mathématiques (Paris : Gauthier-Villars, 1895)
Courses of mechanics (for the École Polytechnique)
Higher algebra (for the Faculté des Sciences)
Mathematical physics (for the Collège de France)