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Roger Cotes

Quick Info

Born

10 July 1682

[Burbage, Leicestershire, England](#)

Died

5 June 1716

Cambridge, England

Summary

Roger Cotes was an English mathematician who edited the second edition of Newton's *Principia*. He made advances in the theory of logarithms, the integral calculus and in numerical methods, particularly interpolation.



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Biography

Roger Cotes' mother was Grace Farmer, who came from Barwell in Leicestershire, and his father was Robert Cotes who was the rector of Burbage. Roger had a brother Anthony one year older than himself, and a sister Susanna who was one year younger. He attended Leicester School and by the age of twelve his teachers had already realised that he had an exceptional mathematical talent. His uncle, the Reverend John Smith, was keen to give Roger every chance to develop these talents and so Roger went to live with him so that he might be personally tutored. Roger later attended the famous St Paul's School in London, but he continued to be advised by his uncle and the two exchanged letters on mathematical topics during the time that Roger spent at school in London.

Roger matriculated at Trinity College, Cambridge, on 6 April 1699 as a pensioner, meaning that he did not have a scholarship and paid for his own keep in College. He graduated with a B.A. in 1702 and remained at Cambridge where he was elected to a fellowship in 1705. In January 1706 he was nominated to be the first Plumian Professor of Astronomy and Experimental Philosophy. This was a remarkable achievement for Cotes who, at that time, was on 23 years of age. His exceptional abilities had been fully appreciated, however, by many at Cambridge such as [William Whiston](#) with whom he had quickly formed a friendship. Both [Newton](#) and [Whiston](#) recommended Cotes for the Chair, as did Richard Bentley who was master of Trinity College. There were some, however, who opposed his appointment, the most high profile of whom was [Flamsteed](#), the astronomer royal. By the time that Cotes was formally elected as Plumian Professor on 16 October 1707 he had, in the previous year, been elected to a more prestigious fellowship as well as being awarded his M.A. Meli gives the background to the establishment of the chair in [2]:-

Cotes was the first occupant of the Cambridge chair established by Thomas Plume (1630 - 1704), archdeacon of Rochester, who bequeathed nearly £2000 to maintain a professor and erect an astronomical observatory. Plans for an observatory at Trinity had already been drafted by Bentley before Plume's bequest. The observatory was eventually housed over the king's or great gate at Trinity College, together with living quarters for the Plumian professor.

It is not entirely clear how successful Cotes was in his role as an observational astronomer. In the first place there are somewhat contradictory accounts of the quality of the instruments in the Cambridge observatory. Cotes designed a transit telescope to add to a collection of instruments which had been purchased or donated. For example [Newton](#) donated a clock which still survives at Trinity College. Bentley, the master of Trinity College we mentioned above, claimed that the Observatory had "the best instruments in Europe" but an assistant who worked there wrote to [Flamsteed](#) saying "I saw nothing there that might deserve your notice". The truth is probably somewhere in between, since it would be natural for the master of Trinity to boast of the facilities, while the assistant, who only worked there for a short time, was probably trying to please [Flamsteed](#). In terms of the observations that Cotes made, perhaps the most significant was the total eclipse on 22 April 1715. However, [Halley](#) describes this event in a paper in

the *Philosophical Transactions of the Royal Society* where he says that Cotes:-

... had the misfortune to be opprest by too much company, so that though the heavens were very favourable, yet he missed both the times of the beginning of the eclipse and that of total darkness.

Cotes himself wrote a letter to [Newton](#) concerning the eclipse in which he explained that his assistant had discovered a method to determine the mid-point of the eclipse and he [3]:-

... called out to me, "Now's the middle", though I knew not at that time what he meant.

None of this speaks very highly of Cotes' dedication as an observer, but nevertheless he did note some important facts concerning this eclipse and other astronomical events. However, his mathematical abilities put him second only to [Newton](#) from his generation in England. Before going on to look at his mathematical contributions let us note that he was elected a fellow of the [Royal Society](#) on 30 November 1711, was ordained a deacon on 30 March 1713, and was ordained a priest on 31 May 1713.

From 1709 until 1713 much of Cotes' time was taken up editing the second edition of [Newton's Principia](#). He did not simply proof-read the work, rather he conscientiously studied it, gently but persistently arguing points with [Newton](#). For example in [6] a discussion is considered which took place between Cotes and [Newton](#) in 1711 concerning the velocity of water flowing from a hole in a cylindrical vessel. During the discussion they gave various approximations to the fourth root of 2 which is approximately 1.189207115. [Newton](#) gave the following [rational](#) approximations (we add decimal values to see their accuracy)

$$\frac{6}{5} = 1.200000000$$

$$\frac{13}{11} = 1.181818182$$

$$\frac{25}{21} = 1.190476190$$

while Cotes gave

$$\frac{44}{37} = 1.189189189.$$

At the beginning of the correspondence between the two men the tone is very friendly. However, toward the end of the task there are signs that they are cooling towards one another (see [3] for details of these letters). In particular although [Newton](#) thanked Cotes in the first draft of a preface he wrote to this edition, he deleted these thanks for the final publication. Cotes himself wrote an interesting preface of his own in which he explained how the study of natural philosophy had developed. First, Cotes explained, came [Aristotle's](#) method which involved naming hidden properties. Then, according to Cotes, came the ideas that all matter was homogeneous. He saw these methods as improvements, yet still retaining certain of the weaknesses of [Aristotle's](#) approach. Although he does not specifically name [Descartes](#) and [Leibniz](#) here, it is clearly an attack on their ideas. Finally says Cotes, comes the method based on first conducting experiments without having preconceived ideas, and then deducing how the world works from the results. These were the methods of [Newton](#) which led to establishing how the basic forces of nature operated.

Cotes only published one paper in his lifetime, namely *Logometria*, published in the *Philosophical Transactions of the Royal Society* for March 1714, which he dedicated to [Halley](#). It contains (in the words that Cotes used himself in a letter to [Newton](#) [3]):-

... a new sort of construction in geometry which appear to me very easy, simple and general.

In this Cotes gave a method of finding rational approximations as convergents of [continued fractions](#), and the author of [6] suggests that this explains how he found the approximation $\frac{44}{37}$ to the fourth root of 2 which we mentioned above.

Cotes was particularly pleased with his rectification of the logarithmic curve as he made clear in a letter to his friend [William Jones](#) in 1712. In particular his work on logarithms led him to study the curve $r = \frac{a}{\theta}$ which he named the reciprocal spiral. Cotes extended the work of [Varignon](#) when he rectified the Archimedean spiral and the parabola of [Apollonius](#), a problem first proposed by [Fermat](#), showing that both have the same integral. His work here was based on the formula

$$\ln(\cos q + i \sin q) = iq.$$

[Jones](#) urged Cotes to publish his work in the *Philosophical Transactions of the Royal Society*, but Cotes resisted this, wishing to support Cambridge and publish with Cambridge University Press. His early death was to prevent publication in his lifetime.

Cotes discovered an important theorem on the n th roots of unity, gave the continued fraction expansion of e , invented radian measure of angles, anticipated the method of least squares, published graphs of tangents and secants, and discovered a method of integrating rational fractions with binomial denominators. His substantial advances in the theory of logarithms, the integral calculus, in numerical methods particularly interpolation and table construction of integrals for eighteen classes of algebraic functions led [Newton](#) to say:-

... if he had lived we might have known something.




According to Edleston [3], Cotes died of a:-

... fever attended with a violent diarrhoea and constant delirium.

He was buried four days later in the chapel of Trinity College.

Some of the work which Cotes hoped to publish with Cambridge University Press was published eventually by [Thomas Simpson](#) in *The Doctrine and Application of Fluxions* (2 Vols, London, 1750). Robert Smith edited Cotes' major posthumous work, the *Harmonia mensurarum* which appeared in 1722. It is fitting at this point to explain who Robert Smith was, and how he interacted with Cotes. In fact he was the son of Cotes' uncle, the Reverend John Smith, and had become friends with Cotes when his uncle had him live in his house as a boy. Later Robert Smith was Cotes' assistant when he was Plumian Professor, and eventually succeeded him as Plumian professor. It was Smith who, many years after Cotes' death, when he was master of Trinity College, had a bust of Cotes erected. This bust, which is shown above, is now in the [Wren](#) library.

Let us return to Cotes' posthumous work the *Harmonia mensurarum* . As well as reprinting *Logometria* it contains the three mathematical works:

1. Aestimatio errorum in mixta mathesis. 
2. De methodo differentiali Newtoniana. 
3. Canonotechnia. 

The first concerns plane and spherical triangles and was much used by astronomers. It contains an early study of the theory of errors. The second develops [Newton's](#) methods of interpolation and was particularly useful in studying orbits of comets. The third work studies numerical integration and also includes further contributions to interpolation.

In 1738, 22 years after Cotes died, Smith published the lectures which Cotes had given on experimental physics *Hydrostatical and pneumatical lectures*.

[Quotations by Roger Cotes](#)
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