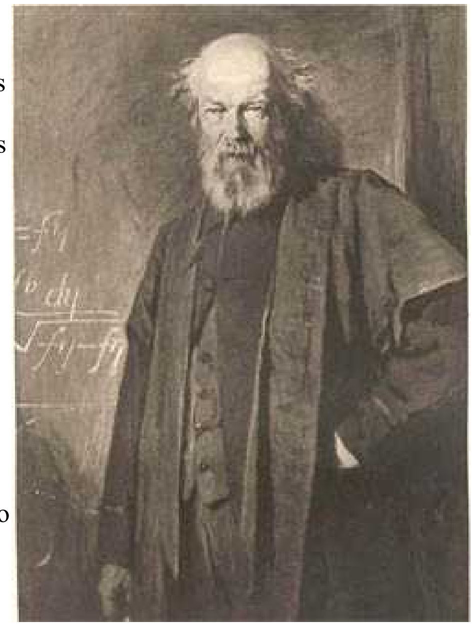
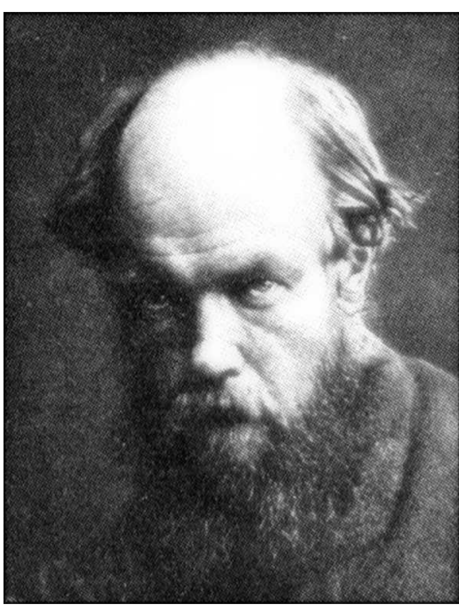
Peter Guthrie Tait



Scottish physicist and mathematician **Peter Guthrie Tait** (April 28, 1831 – July 4, 1901) conducted important investigations in thermodynamics and experiments to determine the density of the ozone and the effects of passing electrical charges through oxygen and other gases. His early work in mathematics dealt mainly with using quaternions in relation to electrodynamics and magnetism. He was one of the first to make a serious study of knot theory, incorrectly believing that this would lead to an understanding of the problems of atoms.

Tait was born in Dalkeith, Scotland, but after his father died, the family moved to Edinburgh to live with his maternal uncle John Ronaldson. A banker by profession, Ronaldson was fascinated with science, particularly astronomy, geology and photography, and he soon interested his nephew in these subjects. At the age of ten, Tait entered Edinburgh Academy where one of his classmates was James Clerk Maxwell. Six years later, Tait went to the University of Edinburgh but stayed only one year before moving to Peterhouse, Cambridge. He graduated as Senior Wrangler in the Mathematics Tripos and also was the First Smith's Prizeman. Although Tait was delighted, later when he was congratulated on the success of a student he had coached for the tripos, he remarked, "Oh, that's nothing – I could coach a coal scuttle to be Senior Wrangler."



This seems a good time to describe Cambridge's famous tripos, which has been alluded to several times in this chronicle. The tripos course is recognized not only as the oldest and one of the most demanding undergraduate mathematics courses available, but also for many the most rewarding. The course is divided into three parts: IA, IB and II, normally taken in successive years. There is a fourth part, called Part IIII, for which one can receive a Certificate of Advanced Study in Mathematics. The range of subjects offered in the mathematical tripos is extremely broad. Students' work is assessed by means of written examinations held at the end of each year. They are assigned coaches who supervise their work and continually judge their progress. Those who score in the top third are named wranglers, and the student with the best grade is called the Senior Wrangler. To illustrate something of the demanding ordeal of the tripos, in 1880, the Senior Wrangler scored 16,368 points out of a possible 33,541 in 36 hours of written work. Nowadays, both the number of points and the length of the examination have decreased considerably. It is traditional that the class lists are read out with great ceremony from the balcony of the Senate House at 9:00 on the Thursday of May Week.

Tait won a Fellowship at Peterhouse, where he collaborated with William Steele, the Second Wrangler, on a text *Dynamics of a Particle* (1856). Tragically Steele died before the project was completed. Tait wrote most of the book but generously published it under both their names. In 1854, Tait was appointed to the Chair of Mathematics at Queen's College Belfast, remaining there for six years at which point he was elected to the Chair of Natural Philosophy at Edinburgh, a post he held until his death. While still at Peterhouse, Tait bought a copy of William Rowan Hamilton's book *Lectures on Quaternions*. He was attracted to the study of quaternions by the promise of their value in physical applications, convinced they could be used to express fluid velocity as a "vector function." When Hamilton died in 1865, Tait became the champion of the use of quaternions. He published the texts *Elementary Treatise on Quaternions* (1867) and *Introduction to Quaternions* (1873). He was embroiled in the controversy over which was more useful, vector theory or quaternion theory, battling with Heaviside and Gibbs, the leading supporters of vectors. In this dispute, Tait ultimately was the loser, as vectors gradually found favor, first with engineers, then physicists and finally mathematicians. Quaternions have made something of a comeback in recent years. In classical physics, they are well adapted to study the rotation group and in modern physics, they are important in the study of Lorentz transformations.

In an 1876 memo communicated to the British Association meeting, Tait detailed some elementary properties of closed plane curves, especially concerning double points, crossings, or intersections. This was the beginning of his study of knots and their properties, with seven papers on the subject published between 1876 and 1877. He was the first to attempt to classify knots of any number of crossings. He established a new vocabulary and gave exact descriptions of terms such as *knottiness, beknottedness, plait, link, lock,* and a Scottish word *flype*, which has no English equivalent, the nearest interpretation being "turn-out-side-in."

Tait collaborated with William Thomson, later Lord Kelvin, on a *Treatise on Natural Philosophy* (1867), which ran through many editions. When Tait thought of an interesting experimental idea, he often referred it to Maxwell or George G. Stokes for evaluation. Sometimes he described the idea in an amusing rhyme to which Maxwell replied in like manner. In his experimental work, Tait was not overly concerned with great accuracy. His methods often lacked polish, but they were always mathematically complete and his intuition was generally correct. After he laid down a broad line of attack, he often left the actual arrangement of experimental apparatus to "veteran" students, but he always gave full credit to those who helped him carry out his ideas.

Tait described himself as a "lecturing machine" appointed by the University to instruct the youth of his country in the "common sense view of the universe we live in." Students were required to present any questions concerning the course material in writing prior to the lectures. Other than this there was little personal contact between teacher and pupil. Tait refused to allow anything to interfere with his official duties toward his class, declining on principle to mention anything unless it had a direct connection with the course. In *An Edinburgh Eleven*, J.M. Barrie gave the following account of Tait as a lecturer:

> "Never, I think, can there have been a more superb demonstrator. I have his burly figure before me. The small twinkling eyes had a fascinating gleam in them; he could concentrate them until they held the object looked at; when they flashed around the room he seemed to have drawn a rapier. I have seen a man fall back in alarm under Tait's eyes, though there were a dozen of benches between them. These eyes could be merry as a boy's, though, as when he turned a tube of water on students who would insist on crowding too near an experiment…."

Tait published a highly biased pro-British account of the history of thermodynamics. A feisty fellow, he argued with Rudolf Clausius and John Tyndall over whether James Joule or Julius Robert von Mayer had priority in proposing the equivalence of work and heat. In all, Tait authored 365 papers and 22 books. He was a devoted supporter of the Royal Society of Edinburgh, serving as its General Secretary from 1879 to his death. In 1873, he purchased the house at number 38 George Square, Edinburgh, which in time became the last privately owned building on the square. In 1964 the University purchased the house from the Tait family to make way for a new library. His family donated a number of books from his private collection to the University, including a first printing of Newton's *Principia*.

Tait was a lifelong golf enthusiast and pioneered modern golf-ball design. With the assistance of his son Freddie, a leading amateur golfer, he performed the first aerodynamic experiments on golf balls. For hundreds of years Scotsmen had driven golf balls over historic links such as St. Andrews, but Tait was the first to raise the question of why a well-driven ball carries so far and remains in the air as long as it does. Most golfers know that a well-struck ball is not the result of mere muscle, but largely is due to skill in making a swing. Tait was the first to realize the question was a dynamical problem that could be precisely stated and approximately solved.

He recalled "We fastened one end of a long untwisted tape to the ball and the other to the ground and induced a good player [Freddie] to drive the ball into a stiff clay face a yard or two off…. the tape is always twisted no doubt to different amounts by different players – say from 40 to 120 or so turns per second. The fact is indisputable."

In 1666 Isaac Newton found that when a spherical ball is rotating and at the same time advancing in still air, it deviates from a straight path in the same direction as that in which the front side of the ball is being carried by the rotation. Early golfers thought all spin was detrimental to distance, but Tait discovered that a ball driven with a "backspin" actually produced lift. He found that a ball driven about a horizontal axis with the top of the ball coming toward the golfer has a lifting force on it that keeps the ball in the air much longer than would be possible without spin. What actually happens is that the backspin imparted by the club on impact at thousands of revolutions per minute causes the ball to behave like the wing of an airplane. Air flows more quickly over the top of the ball than the bottom. As Tait put it, "in topping, the upper part of the ball is made to move forward faster than does the center, consequently the front of the ball descends in virtue of the rotation, and the ball itself skews in that direction. When a ball is undercut it gets the opposite spin to the last, and, in consequence, it tends to deviate upwards instead of downwards. The upward tendency often makes the path of a ball … concave upwards in spite of the effects of gravity…" Tait published several scholarly articles describing his experiments and findings. He was also the first to experiment with furrowing the face of a club with a number of parallel grooves to improve their driving power by affording a better grip on the ball. Later research has shown that a larger spin produces a larger drag, which makes the ball slow down more rapidly and thus decreases the distance it travels. On the other hand a larger spin produces more lift, which keeps the ball in the air for a longer time and thus allows it to fly farther. The appropriate ratio of lift to drag depends upon the individual player. Recently, physicist Raymond Penner of Malaspina University College in British Columbia, Canada, established that harder hitters get better results with clubs of lower loft.

Quotation of the Day: "In future times Tait will be best known for his work in the quaternion analysis. Had it not been for his expositions, developments and applications, Hamilton's invention would be today, in all probability, a mathematical curiosity. – Andrew Macfarlane