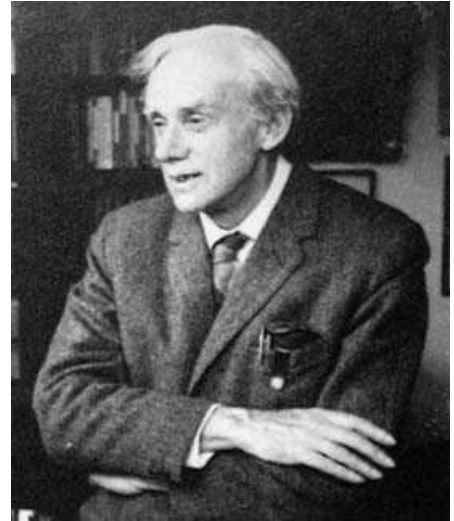


## **P.A.M. Dirac**

British theoretical physicist **Paul Adrien Maurice Dirac** (August 8, 1902 – October 20, 1984), one of the most gifted mathematical thinkers of the 20<sup>th</sup> century, was driven by a search for beauty and elegance in the equations he developed. He is best known for his work in quantum mechanics and for his theory of the spinning electron. In 1930 he formulated a quantum theory for the motion of electrons in electric and magnetic fields. The famous “Dirac equation” reconciled Austrian physicist Erwin Schrödinger’s earlier quantum theory and Einstein’s theory of relativity. Dirac’s pioneer work earned him the Nobel Prize for Physics in 1933, which he shared with .



Dirac was convinced that mathematics is the key to progress in physics. Late in his career, he explained his credo: “One should allow oneself to be led in the direction which the mathematics suggests ... one must follow up a mathematical idea and see what its consequences are, even though one gets led to a domain which is completely foreign to what one started with.... Mathematics can lead us in a direction we would not take if we only followed up physical ideas by themselves.” He went on to say: “I learned to distrust all physical concepts as the basis for a theory. Instead one should put one’s trust in a mathematical scheme, even if the scheme does not appear at first to be connected with physics. One should concentrate on getting interesting mathematics.”

Dirac was born at Bristol, one of three children. His mother was English and his father Swiss and very strict, so intent on having his children learn French that he refused to speak to them unless they spoke in correct French. This may explain why Dirac was a man of few, carefully chosen words. He once

said, "I was taught at school never to start a sentence without knowing the end of it." He avoided company and his favorite pastime was taking solitary walks. Both Paul and his older brother Reginald became alienated from their father. Reginald committed suicide in 1925, which brought Paul's already strained relationship with his father almost completely to an end, indicating he felt his father shared some of the blame for the tragedy. When Dirac was told he could invite his parents to his Nobel Prize ceremony, he invited only his mother.

Dirac was educated at Bishop Primary School and the Merchant's Ventures Secondary School where his exceptional mathematical ability became apparent. In 1918, he entered Bristol University to study electrical engineering, graduating with first class honors in 1921. Fascinated by Einstein's theories of relativity, Dirac won a scholarship to Cambridge but it did not provide enough money to support him. He was allowed to study mathematics at Bristol for two years without paying any fees, again graduating with first class honors in 1923.

The next year Dirac was awarded a grant to do research in theoretical physics at St. John's College, Cambridge, working at the famous Cavendish Laboratory. Within two months of his arrival at Cambridge, he wrote two papers on problems in statistical mechanics. He had eleven papers in print before submitting his doctoral dissertation *Quantum mechanics* for which he was awarded a Ph.D. in 1926. He traveled to the Continent to visit and work with physicists Niels Bohr at Copenhagen and J. Robert Oppenheimer, Max Born, James Franck and Igor Tamm at Göttingen. Dirac returned to Cambridge where he was elected a Fellow of St. John's College in 1927. Five years later he was appointed Lucasian Professor of Mathematics, holding the post for 37 years. He researched the theoretical aspects of the new quantum mechanics [laws of motion that govern atomic particles], first introduced by Werner Heisenberg. Dirac independently produced a mathematical equivalent of quantum mechanics consisting of a noncommutative algebra for calculating atomic properties.

Extremely shy, when informed that he was to share the 1933 Nobel Prize of Physics with Schrödinger, Dirac told Lord Rutherford, the head of the Cavendish Laboratory, that he did not wish to accept the prize because he disliked publicity. Rutherford advised him to accept it, for to refuse it would bring even more publicity.

Mathematically speaking, relativity theory and quantum theory are not only distinct, but oppose each other. Dirac's goal was to formulate atomic laws in the most elegant mathematical language. His revolutionary idea was that the electron could be described by four wave functions, satisfying four simultaneous differential equations. With his quantum theory of the electron, Dirac replaced wave equation with more general equations. As the equations are solved, various properties of the electron, such as spin and magnetic moment appear. The properties of the solutions to the equations mystified scientists until Dirac predicted that negative energy states must correspond to the existence of a positive electron or "anti-electron," that is, there must exist another type of particle with exactly the same mass as the electron, but with positive instead of negative electric charge. This antiparticle of the electron particle, called the *positron*, is the first example of antimatter. Carl Anderson experimentally verified the existence of the positron in 1932, when he obtained cloud chamber photographs showing the existence of positrons, the positive antiparticle of electrons, having approximately the same mass and magnitude of charge, thus confirming Dirac's remarkable prediction.

Dirac was awarded the Royal Society's Royal Medal in 1939 and its Copley medal in 1952, but due to his shyness refused to accept honorary degrees. In 1969 Dirac retired from Cambridge and moved with his family to Florida where he was appointed professor of physics at Florida State University. His wife Margit Wigner, whom he married in 1937, was the sister of noted Hungarian physicist Eugene Wigner. She had been married before and had two children Judith and Gabriel. Both children adopted the name Dirac and Gabriel went on to become a well-known pure mathematician at the University of Aarhus in

Denmark. Paul and Margit had two other daughters, Mary Elizabeth and Florence Monica. Dirac continued his research until his death in Tallahassee in 1984. In 1995 a plaque [Figure 8.8] to Dirac was unveiled in Westminster Abbey, London, making Dirac's equation the first to appear in the Abbey. Speaking at the ceremony Stephen Hawking observed, "Dirac has done more than anyone this century, with the exception of Einstein, to advance physics and change our picture of the universe."

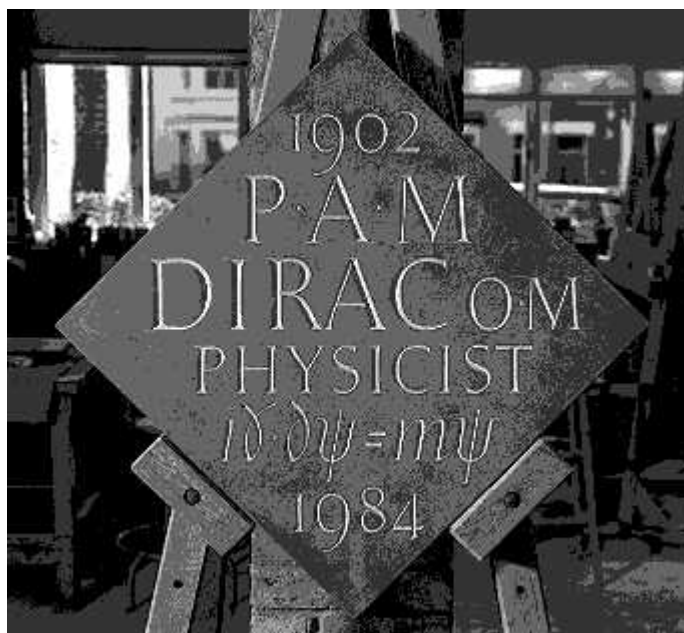


Figure 8.8

It wouldn't do to end this article without relating a few anecdotes about our colorful subject. Although eloquent in writing, Dirac was known for saying exactly what he meant and no more. At a dinner party another guest making polite chitchat observed that it was quite windy. Allegedly Dirac got up from the table, marched to the door, opened it, looked outside, returned to the table, sat down, and told his companion, "Yes, it is windy." At the question period after a Dirac lecture at the University of Toronto, someone in the audience remarked, "Professor Dirac, I do not understand how you derived the formula on the top left side of the blackboard." "This is not a question," snapped Dirac, "It is a statement. Next question, please."

**Quotation of the Day:** “God used beautiful mathematics in creating the world” – P.A.M. Dirac [It is interesting that Dirac who was a committed atheist would say this. Asked to give his thoughts on Dirac’s views, Austrian-born theoretical physicist Wolfgang Pauli said, “If I understand Dirac correctly, his meaning is this: there is no God, and Dirac is his Prophet.”]