HERMANN MINKOWSKI

Russian-born German mathematician **Hermann Minkowski** (June 22, 1864 – January 12, 1909) evolved a four-dimensional geometry of space that was essential to the formulation of the general theory of relativity. He realized that the special theory of relativity, introduced in 1905 by Albert Einstein, could be best understood in a non-Euclidean space, which has come to be known as "Minkowski space." Minkowski put forth his concept of space-time in his book *Raum and Zeit* (1907, Space and Time*)*, in which he considered space and time, formerly thought to be independent, to be fused together in a four-dimensional "space-time continuum." He recognized that although different observers experience the same events, they might *describe* them differently because they disagree about the nature of space and the nature of time. But taken together space and time form a powerful unity. This concept erased the bounds of conventional Euclidean geometry and Newtonian physics.

Minkowski was born in Alexotas, Lithuania, then a part of the Russian Empire. At the age of eighteen while still a student he won the "Grand Prix des Sciences Mathématiques" awarded by the Paris Academy of Sciences, for his essay on the decomposition of integers into the sum of five squares. Minkowski studied at the Universities of Berlin and Königsberg, receiving his doctorate from the latter in 1885, a few months after his life-long friend David Hilbert obtained his. Minkowski was professor at Königsberg (1895) and Zürich (1896), where one of his students was Albert Einstein. One of the most likeable of mathematicians, Minkowski jokingly told his later students that Einstein's presentation of the theory of relativity was mathematically awkward. He told them, "I can say this because Einstein received his mathematical education from me."

In 1902 Minkowski accepted a chair, newly established just for him, at Göttingen, where he stayed for the rest of his life, working closely with Hilbert. Minkowski used geometric methods to solve complicated problems in number theory, mathematical physics, and the theory of relativity, creating a new field, "the geometry of numbers." He applied his conclusions to the study of convex bodies, analyzing their geometric properties. In doing so he earned credit for establishing the foundation of modern functional analysis.

Prior to Minkowski's invention of the space-time model, Einstein and others considered the Special Theory of Relativity to be primarily a physical theory. They did not focus on the geometrical implications of the new physics. The physicists of the day were primarily concerned with devising a new mechanics consistent with the postulates of the special theory. It was Minkowski who studied the mathematical structure of the new theory and its geometrical implications.

One implication of his work is that spatiotemporal measurements by an observer are a function of the stage of motion of the observer with respect to what is being measured. If two different observers are in different relative states of motion with respect to something being measured, then their respective measurements will not agree. When Einstein learned of Minkowski's space-time formulation, he became convinced that the economy and simplicity of Minkowski's approach to the theory could not be accidental. Minkowski's "geometric" approach was the key to Einstein's development of a theory that incorporated both the special theory of relativity and the effects of gravity. Minkowski had less success with another famous problem. He once told his students that the reason the Four-Color Map conjecture had not been settled was because only third-rate mathematicians had worked on it. He claimed, "I believe I can prove it." After a long period, he admitted, "Heaven is angered by my arrogance, my proof is also defective."

One Sunday in 1864, Minkowski was stricken with a ruptured appendix, and by the next day his condition grew worse. Aware of the hopelessness of his situation, he attempted to correct the proof sheets of his latest work. When visited by Hilbert, Minkowski expressed his regret that he would not be able to accomplish all he had hoped to do and that he would miss Hilbert's upcoming lecture on the *Waring problem*. On Tuesday he asked to see his family and Hilbert, but by the time the latter arrived Minkowski was dead at age forty-four.

Quotation of the Day: "The views of space and time that I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth, space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality." – Hermann Minkowski