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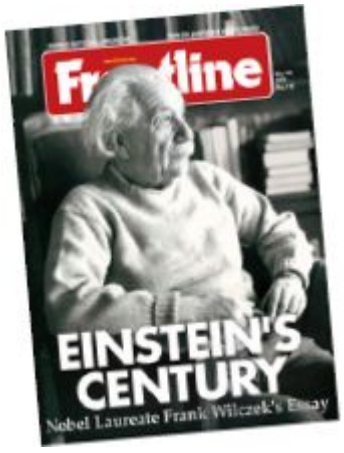
SCIENCE

Einstein’s century

On Albert Einstein's legacy, in the World Year of Physics 2005, a hundred years after he initiated a revolutionary turn away from classical physics with his seminal papers. Excerpts from the article by T. JAYARAMAN for the May 20, 2005, issue.



IN the spring of 1905, a young man began the journey from obscurity to scientific stardom. Within a decade, he would be hailed as a genius who towered over his contemporaries, even in an era that had no dearth of brilliant minds in science. Soon the comparisons would begin to transcend his century, and he would take his place alongside Isaac Newton and Charles Darwin. In that magical year, the 26-year-old Albert Einstein, without a formal academic position and sustained by employment in the Swiss Federal Patent Office, was to publish four epochal papers within the space of seven months in the German journal *Annalen der Physik*, one of the pre-eminent scientific journals of his time. Physics would no longer be the

same after 1905. The comforting link between mundane sensory experience and the fundamental laws of nature that had existed in Newtonian physics even after the Copernican revolution would now be lost forever.

What did Einstein accomplish in those four papers of 1905?

Three days after his 26th birthday, on March 17, Einstein completed the first of this remarkable series. Published on June 9, the paper was titled “On a heuristic point of view concerning the generation and conversion of light”. This paper was the first shot in the quantum revolution. In this paper Einstein framed, unambiguously, the hypothesis that light in its interaction with matter behaves like a particle with a discrete amount, or ‘quantum’, of energy proportional to its frequency. Over the next two decades the hypothesis was to be verified experimentally, leading to his Nobel Prize for physics in 1921.

The second paper, published in the issue of July 18, concerned itself with the explanation of Brownian motion, the phenomenon of random motion executed by particles suspended in a fluid. The work was an immediate outgrowth of his doctoral thesis. This paper, as Einstein cheerfully noted in a letter to a friend, once and for all settled the question of the reality of atoms. It also developed methods that lie at the root of modern statistical physics, particularly in the study of systems out of equilibrium.

Some time in mid-May, Einstein had that definite moment of discovery that opened the road to the formulation of the special theory of relativity. The result was the third paper, published on September 26, titled “On the electrodynamics of moving bodies”. It abolished the notion that electromagnetic radiation required some kind of medium, the ‘ether’ as it was known, for its transmission. Einstein also postulated that the velocity of light was always constant, independent of the velocity of the emitter.

In the resulting unification of space and time, Einstein advanced decisively beyond Newtonian mechanics, a process that he was to complete with the general theory of relativity in 1915. The mathematician Hermann Minkowski, one of the few teachers from his university days that Einstein respected, noted in an influential review of the theory of relativity in 1908: “The views of space and time which 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."

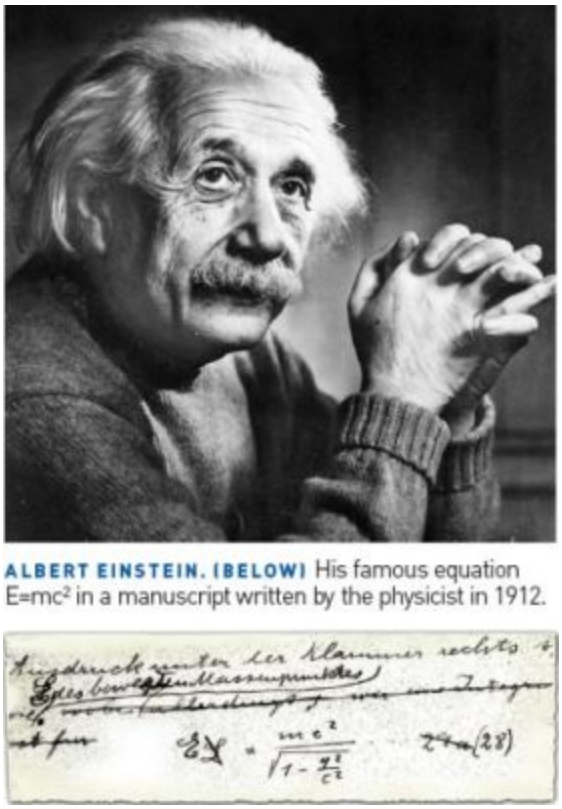
In the fourth paper, published on November 21, Einstein announced the result that energy is proportional to mass, as a consequence of the special theory of relativity. The constant of proportionality is the square of the speed of light.

Within months of the publication of these four papers, Einstein had arrived in the academic world of his time. By 1906, he was in correspondence with leading physicists of his day like Max Planck, who was to describe Einstein some years later as a "modern Copernicus". Three years later Einstein was to leave the patent office to enter the academic world, but the legend of the unknown patent clerk, the lonely genius, who effected a complete revolution in science was born.

In 1915, he succeeded in extending the theory of relativity to matter in acceleration, resulting in a new theory of gravitation, where mass was identified as the curvature of space-time. But this was hard won success, and the final work was built on a succession of earlier papers, some of them in collaboration with Marcel Grossman, his friend from his university days. The confirmation of this theory came from the solar eclipse expedition of 1919, data from which revealed the bending of light from the stars by the sun, which had been predicted by Einstein's new theory of gravity.

Subsequently, Einstein's scientific journey was to become more complex and difficult. He never reconciled himself to the eventual form that quantum mechanics took in the hands of Werner Heisenberg, Paul Dirac, Erwin Schrodinger and Max Born, under the influence of Niels Bohr.

While he was gradually convinced that quantum mechanics was not inconsistent, he nevertheless believed that it was incomplete. Einstein liked even less the application of the methods of quantum mechanics to electromagnetic fields. The man who initiated the quantum revolution remained unhappy with what became of it in the hands of its Jacobins.



ALBERT EINSTEIN. (BELOW) His famous equation $E=mc^2$ in a manuscript written by the physicist in 1912.

Albert Einstein. (Below) His famous equation $E=mc^2$ in a manuscript written by the physicist in 1912.

Thus began an isolation from the mainstream that was to intensify in his years at the Institute of Advanced Study at Princeton in the United States, where he settled after leaving Nazi Germany in 1933. His attempts in his Princeton years to formulate a unified theory of gravitation and electromagnetism did not make much progress and was considered a fruitless project by many of his contemporaries. Twentieth-century science pushed forward far more relentlessly than the science of the 17th or even the 19th century, and the manner in which scientific developments outran Einstein in his later years was not a fate that befell a Newton or a Maxwell in their lifetime.

But Einstein's larger vision undoubtedly set the agenda, if only in part, for subsequent developments that came much later. The search for a unified theory of all fundamental forces has now become an integral part of the paradigm of fundamental physics. And in partial vindication of Einstein, the integration of quantum mechanics and the general theory of relativity on the basis of some fundamental principles remains a challenge despite evidence of some progress in recent decades.

After the spectacular affirmation of Einstein's theory of gravity by the solar eclipse expedition of 1919, a world wearied by the First World War greeted Einstein as a new popular hero. There was intense interest worldwide in Einstein and his work. In India, it resulted in the publication of the first-ever English translation of the papers of Einstein and Minkowski by Satyendranath Bose and Meghnad Saha, with a foreword by P.C. Mahalanobis.

Even prior to his rise to fame, Einstein had begun to step out into the world of public affairs, signing a manifesto against German militarism in 1917. Einstein was to be a pacifist all his life, except for the period that the Nazis were in power, and was drawn naturally to the ideals of Gandhi. Though he signed the letter urging the U.S. President to develop the atomic bomb, he was horrified by its use. He was unwaveringly opposed to nuclear weapons and it was a cause that occupied him until the end of his days.

Einstein was one of the few intellectuals in the U.S. to speak up against the anti-communist witch-hunts of the McCarthy era. In 1949, he wrote a short note titled "Why Socialism?" for the inaugural issue of the communist journal *Monthly Review*. For several years the Federal Bureau of Investigation (FBI) kept him under surveillance. Einstein, though, remained an undaunted champion of civil liberties.

Einstein, born in an irreligious Jewish family, had no great attraction for religion through most of his life. But he was a firm supporter first of Zionism and then the state of Israel and lent his name to several other Jewish causes through the years. Shocked by the Holocaust, which claimed the lives of several of his relatives including two cousins, he shunned all contact with Germany, the land of his birth, except for a few close friends.

What was the origin of Einstein's willingness to support causes that went against the mainstream and were certainly unpopular with those in positions of power? Perhaps it was an extension of his scientific spirit to the realm of human affairs, as Niels Bohr noted in his obituary on Einstein: "The gifts of Einstein are in no way confined to the sphere of science. Indeed, his recognition of hitherto unheeded assumptions in even our most elementary and accustomed assumptions means to all people a new encouragement in tracing and combating the deep-rooted prejudices and complacencies inherent in every national culture."

Yet to Einstein himself, despite his considerable involvement in matters other than science, especially in his later years, his scientific work was always to be at the core of his being, the

very definition of his persona. His scientific writings number more than 300, a large output even by contemporary standards. In his last days at Princeton, he continued to be held in awe by his scientific colleagues, even if they did not follow what he said. He lived quietly, walking every day between his office at the Institute of Advanced Study and his home, where he was ministered to by his faithful secretary Helen Dukas. To the men, women and children of that little town, the grandfatherly figure was a gentle and benevolent presence.

Einstein died on April 19, 1955, at the age of 75, after a brief stay in hospital following a ruptured aneurysm.

URL: http://www.frontlineonnet.com/fl2701/stories/20100115270113900.htm