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BOOK REVIEW

E=mc^2 *A Biography of the World's Most Famous Equation*

David Bodanis
New York: Berkley Books, 2000.
ISBN: 978-0425181645
Price: Rs 450/-

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The book *E =mc^2, A Biography of the World's Most Famous Equation* by David Bodanis is an extremely good read for anyone interested in the evolution of sciences. It deals with the Special Theory of Relativity, a much talked about but not so well understood facet of modern physics. This is not a book on science, neither is it conventional popular science. It is a biography of an equation. The author does not explain the meaning of the equation; he explains the history of the equation, the meaning just sneaks in.

The credit for writing such a good book goes to the once elusive author, David Bodanis, about whom nothing is written in the book and very little was available on the internet till recently. Today he maintains his own website and all his books are prominently displayed there. (http://www.davidbodanis.com/)

In the preface to the book, the author presents an interesting anecdote, as to why the book was written in the first place. "*…I was reading an interview … actress Cameron Diaz … At the end, the interviewer asked her if there was anything she wanted to know, and she said she'd like to know what E=mc^2 really means. They both laughed, then Diaz mumbled that she'd meant it….*

"You think she did mean it?" one of my friends asked after I read it aloud. I shrugged, but everyone else in the room—architects, two programmers, and even one historian ...—was adamant. They knew exactly what she intended: They wouldn't mind understanding what the famous equation meant too. It got me thinking. Everyone knows that $E=mc^2$ *is really important, but ... don't know what it means...."*(vii)

The book starts with *E*, the energy and explains how the concept entered the minds of scientists with the pioneering work of Michael Faraday. We also get a glimpse of the world of those days and the lives of scientists of the time. The struggle that a poor apprentice of a bookbinder (Faraday) faced is described in graphic details. The fact that energy remains a constant comes out in details. The fact that lightning, the opening of a door or a horse pulling a cart are related through the concept of energy is shown in great clarity. In particular, two isolated subjects, namely electricity and magnetism combine to become a new single field called electromagnetism.

Then comes the history of *m*, the mass. This starts with Antoine-Laurent de Lavoisier, the chief tax collector of Paris, who performed ultra-accurate experiments, far ahead of his times, to show that the total mass remains constant in any process, provided the measurements are made very accurately. The first experiments were conducted on the rusting of iron, where the addition of oxygen to iron increases weight, in contradiction to what was then believed. The careful measurements of Lavoisier showed that the weight actually increases, and the increase is precisely equal to the weight of oxygen added. He performed the experiment in reverse to measure the mass of oxygen evolved. This showed that the mass remains conserved, no matter how things may appear to change. The story talks in parallel with Lavoisier's work as a tax collector, which led to widespread unrest during the French Revolution. This unrest and subsequent events finally led to his execution.

The importance of *c*, the speed of light is generally underestimated. *c* stands for celeritas, the Latin word for swiftness. The importance of this quantity has been described in detail, as it provides the connection between the apparently isolated phenomena of electromagnetism and light. The story touches Faraday, now an old man and his young friend, James Clerk Maxwell, who provided the necessary mathematical background to support Faraday's ideas and immortalised electromagnetism in four elegant equations which now carry his name.

The most underestimated part of the equation is the square, but Bodanis deals with it in his characteristic manner. He takes the story to France of the early 1700s, to a young girl whose father had said "*My youngest flaunts her mind, and frightens away the suitors. . . .don't know what to do with her*".(58) Meet Emilie de Breteuil, the youngest daughter of a rich French nobleman. When all other girls used their beauty to find a husband, she was reading Descartes' Analytical Geometry. This was the time that the ideas of Newton were entering France in a big way, and the Newton – Leibniz conflict intrigued Emilie. Newton proposed that the total quantity of motion in a body is given by its mass multiplied by its velocity. Leibniz proposed that it was mass multiplied by the square of the velocity. The conflict was difficult to resolve, with the British going for Newton and the Germans for Leibniz. It was the neutral and intelligent approach of Emilie that showed the merits of both approaches. Physicists today study both momentum or mass multiplied by velocity and kinetic energy or half of the mass multiplied by the square of velocity. This was the first use of a square in an equation in physics.

The story now comes to Einstein, working as a clerk in the Swiss Patent office. He challenged the two accepted facts of the time, the conservation of mass and conservation of energy. He showed that neither mass nor energy is conserved, they are but two facets of the same quantity, and the total is conserved. Mass can be converted into energy and vice versa, and are connected by the equation which is the title of the book. The fact that the mass gets multiplied by c squared when converted to energy shows that a huge amount of energy can be generated from a very small mass. Einstein's work, published in 1905, was accepted with acclaim after a few years.

The story then records further developments of this remarkable theory. The Second World War compelled the making of the atom bomb using this idea a necessity, both for Germany and the USA, which led to immense research efforts. The destructive results are too well known for any more comments.

Other offshoots of this result are no less remarkable, albeit not so well known. The immense energy released by the sun had fascinated generations of physicists. Cecilia Payne showed that this is due to the combination of four hydrogen atoms to form a helium atom. The helium atom weighs less than the four hydrogen atoms. This extra mass is

released as energy. She was not allowed to publish her thesis in the original form, she had to write an apology that the presence of so much hydrogen in the sun is unlikely. The difficulties of a woman in fundamental research in the 1920s and 30s come out in detail.

Here in comes an Indian connection. Subrahmanyan Chandrasekhar was on his way to Cambridge in 1930. It was a long and mostly quiet cruise, and he was armed with sheaves of paper and a habit of using his spare time productively. English racism helped, for the white children were normally not allowed to interact with a dark-skinned Indian. At that time it was known that giant stars would explode. Their outer portions would be thrown in space and the inner core would remain. Chandrasekhar knew that the core is under a lot of pressure, and he had the time to think about what happened to it. The gravity in this remnant star becomes very high, due to the fact that the pressure is a kind of energy, which manifests as a mass. This increases the pressure and creates a "catch-22" situation where the gravity keeps increasing, wherein the remnant star keeps getting crushed. What does this lead to? This would lead to a situation where nothing would escape outside; everything would be sucked in – the concept of a black hole. The first evidence for this phenomenon came in 1960, when a star appeared to spin around an area which did not show any other star – there was a black hole there.

The book also speaks of Einstein's other contributions. Finally it ends in a chapter on follow-ups on the lives of the players described in the book, one on further technical details for those interested, and finally one on suggestions on further reading.

Let me hazard a guess at the end. If Cameron Diaz has read the book, she has understood what the equation means. Definitely, a book to be read by scientists and non-scientists alike, a must read for every curious intelligent person.

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