The Expanded Quotable Einstein. Collected and Edited by Alice Calaprice. Princeton University Press, NJ. 2000. 407 pp. Price not mentioned.

'If you wish to learn from the theoretical physicist anything about the methods which he uses, don't listen to his words, examine his achievements.'

– Einstein–Herbert Spencer Lecture 1933

The international year of physics marking the centenary of Einstein's miraculous year 1905, has just concluded. We should hope that the public at large appreciates Einstein's achievements in physics instead of blindly adoring him.

The successful verification of Einstein's theory of gravitation in 1918 made him not just a great physicist to be ranked with Newton, but also made him a public figure. After his death, many details of his personal life have become public. So there are at least three Einsteins, the physicist, the public figure and the private human that emerge in this book of quotations.

Fundamental physics today rests on two pillars – one, standard cosmology, the other called the standard model of elementary particles and their interactions. Cosmology is largely based on Einstein's gravitational field equations. While Einstein had no role in the evolution of the standard model, invariance principle, the central theme in relativity theory, plays a vital role in the construction of the standard model. It is no exaggeration to say that Einstein's spirit and vision permeate physics.

Einstein spent nearly a decade from the age of sixteen thinking about properties of light, i.e. electromagnetic waves, before arriving at his special theory of relativity. The other great problem that engaged young Einstein was Planck's quantum theory of black-body radiation invented in 1900. Einstein, in 1905, reintroduced the corpuscular theory of light to explain the photoelectric effect. The light wave was now to be regarded as a collection of photons with individual photons having energy proportional to the frequency. This work which earned him the Nobel Prize, was completed a few months before his relativity paper. It also helped him to overthrow the notion of ether and reject the notion of an absolute frame of reference, a decisive step in arriving at relativity theory. The third significant paper by Einstein on Brownian motion, by his own account, took much less effort than either his work on special relativity or the photoelectric effect. The miraculous year 1905 is in a sense a coincidence of several years of work on many ideas coming to fruition about the same time.

The term 'theory of relativity' does not quite communicate the role that invariance principle plays in Einstein's thinking. In fact, Felix Klein had suggested the term 'theory of invariants', which would have been better considering that the word 'Relativity' when translated in other languages may not quite mean what Einstein had in mind.

But what exactly is an invariance principle? Consider, for example, head-on collision of two balls of different sizes with some given initial velocities before collision. If we do an experiment to find the after-collision values of the velocities, one finds that the answer does not depend on when the experiment is done – in the morning or evening, yesterday or today. In other words we have invariance under translations in time, i.e. moving the experiment from one instant of time to some other instant is inconsequential as far as results of observations are concerned.

It was his insistence that all laws of physics, including electromagnetism as well as mechanics be invariant, i.e. take the same form in any inertial frame coupled with the hypothesis that the velocity of light is a constant independent of the velocity of its source that led Einstein to critically examine the concept of time and to the theory of relativity. In his own words (p. 228), 'My solution was to analyze the concept of time. Time cannot be absolutely defined and there is an inseparable relation between time and signal velocity'.

Soon after his 1905 triumph, Einstein took up the challenge of extending his ideas to gravitation theory, which he successfully completed in 1915. While this theory has become standard textbook material, a good historical presentation of this heroic effort 'The years of anxious searching in the dark for a truth that one feels but cannot express, the intense desire and the alternations of confidence and misgiving until one achieves clarity and understanding…' (p. 248) still needs to be written.

Einstein played a central role in the development of quantum theory. Introduction of the light quanta which he himself considered to be revolutionary, paved the way for Bohr to discover his model of the atom. Einstein was generous towards the younger physicists with his brilliant suggestions and critical questions. To mention only a few, he encouraged de Broglie to pursue the idea of matter waves for which he found support from his own work on statistical fluctuations. He pointed out to Schrödinger that the wave equation in the latter's draft paper did not satisfy linearity or the all important superposition principle and wrote down the correct equation. (Meanwhile Schrödinger himself corrected the mistake.) He goaded young Heisenberg to come up with an explanation why it is not alright to talk about the trajectories of an electron in an atom, while experimentally one can see electron tracks in a cloud chamber. (Heisenberg did and found the uncertainty principle.) He heralded the paper by Bose for its novel derivation of Planck's radiation formula and extended it to ideal gases and predicted a new phase of matter now referred to as Bose–Einstein condensate.

Einstein spent far more of his intellectual energy on quantum theory than on relativity. As he himself put it (p. 260) 'I have thought a hundred times as much about the quantum problems as I have about general relativity theory'. And again 'All the fifty years of conscious brooding has brought me no closer to the answer to the question, "What are the light quanta?". Of course today every rascal thinks he knows the answer, but he is deluding himself'. What is this strange element in quantum theory that made him believe that present-day quantum mechanics is not the final form of the theory. Quantum theory describes dynamical evolution of physical systems in the language of transformation of vectors in an abstract space in contrast to classical theory, which deals with positions and velocities of particles. Physical states represented by vectors can be added or superposed in a manner that has no place in classical physics. Quantum dynamics therefore has novel features not encountered before. Entangling two particles by superposition has the consequence that two distant particles like photons separated by several kilometres can be correlated in quantum theory in a manner that looks like 'spooky action at a distance'. In other words, non-local. When one realizes that Einstein's gravitation theory did away with Newtonian action at a distance it is easy to appreciate why quantum non-locality was not acceptable to him. Einstein along with Podolsky and Rosen (EPR), in a seminal work in 1935 claimed because, non-local or spooky action at a distance is impossible in physics, quantum mechanics is an incomplete theory. A clear method to look for these quantum 'non-local' correlations was suggested by Bell in 1964 and they have been experimentally established only in recent times. Unfortunately, Einstein's position is not supported by experiment. Einstein disliked pompous claims. According to Asher Peres, 'Podolsky released the contents of the EPR paper to the *New York Times* in a way implying that the authors had found that quantum mechanics was faulty. This infuriated Einstein, who after that no longer spoke with Podolsky'.

Strange are the ways by which applications emerge from basic ideas in science. Einstein's work studying the properties of an atom in a radiation-filled cavity led him to introduce the idea of stimulated emission, paving the way for the discovery of the laser almost fifty years later. The entangled pair introduced by EPR in 1935 has become a resource in lithography, cryptography and communications. Who could have imagined that the most abstract of all, Einstein's gravitation theory is crucial for GPS (global positioning system), which can help rescue a stranded person or guide a bomb to its destination.

It is interesting to compare Einstein with Gandhi, whom he admired a great deal. To quote (pp. 82–83) 'Gandhi, the greatest political genius of our time... gave proof of what sacrifice man is capable of once he has discovered the right path' and again 'Gandhi's development resulted from extraordinary intellectual and moral forces in combination with political ingenuity and a unique situation'. We can find an echo in Einstein, exceptional intelligence combined with extraordinary tenacity and single-minded pursuit of the goal he set himself, his struggle for utmost clarity and his refusal to accept, unlike some of his great contemporaries, that there is any limitation to understanding the ultimate reality.

There is an interesting anecdote. Einstein was putting together some sheets of paper, and had a clip that was bent. He went on to get a pair of pliers to straighten the clip while his collaborator went looking for a new clip, and found one. Meanwhile Einstein had set right the bent clip and said 'when I set myself a task I do not give up'.

In this book, one finds many quotations on philosophical, religious, ethical and other issues as well. Suffice to say Einstein's impact on our understanding of space and time and nature of reality will continue to be deep and profound.

Finally, at a personal level, Einstein in his life seems to have experienced more sorrow than happiness. One may empathize with him, but many will be perplexed by the events surrounding his divorce from his first wife Mileva and complex relations he had with his cousin Elsa, whom he eventually married while he was simultaneously courting her daughter Ilse. All the more so when one realizes all this happened during the period in his life when he created the general theory of relativity, one of the great accomplishments of the human mind.

If I am permitted to use an analogy from statistical physics, a subject that was dear to Einstein, to understand his transition from great to immortal, the physicist in him is the relevant one, the philosopher is a marginal one and his private life is irrelevant.

There is a good bibliography at the end of this book. The great physicist Schwinger's book *Einstein's Legacy* (Scientific American Library, 1986), which gives an extremely lucid account of Einstein's achievements, should have been included. Apparently, Schwinger's work was originally meant to be beamed on the television, but sadly did not get enough sponsorship. Perhaps whatever audio-visual material that is available could be distributed as CD today.

It is entirely superfluous to commend this book – it is difficult to see how anyone will not be interested in it. I hope there will be translations in at least a few Indian languages. When that is done, an appendix consisting of useful websites, documentaries and films on Einstein can be included.

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India's Legendary Wootz Steel: An Advanced Material of the Ancient World. Sharada Srinivasan and Srinivasa Ranganathan. National Institute of Advanced Studies, Bangalore and Indian Institute of Science, Bangalore. 2004. 146 pp. Price not mentioned.

The current publication on India's Wootz steel is a pleasing and timely one on a remarkable material from ancient India. It has continued to fascinate soldiers, artisans and scientists alike from various parts of the world right down to the twenty-first century. It is a result of a partnership between Sharada Srinivasan who has been working for over fifteen years on archaeometallurgy and Srinivasa Ranganathan, a senior metallurgist (who was the Chairman of the Study Group for the metallurgical heritage of India constituted by the Indian National Academy of Engineering). The book has been commissioned by Tata Steel, Jamshedpur who have also supported its publication. As the authors have pointed out correctly, Wootz is an important material in metallurgical history originating from India and there are no books by Indian authors on this subject. They have stated that this book has been '...oriented towards a wider readership inclusive of school and college students'. They have produced a book that has lived up to this objective to a large extent.

The book is divided into ten chapters and it takes the reader through a vast panorama of evolution of materials spanning a period of about thirty centuries. They trace the evolution of materials starting from the stone age and interestingly enough, they have a broad concept of materials which includes not only various metals and alloys, but also silk and diamond. The initial chapters take us through the iron age and then introduce the evolution and spread of swords through the ages in various countries. They then go on to discuss about the role of Wootz and the crucible steel in Indian armoury. This is written in a delightful style, which is easily readable by and large without sacrificing any technical rigour.

The second half of the book starts from the period of the European excitement and studies relating to Wootz from the sixteenth century onwards. It traces in detail the varied studies carried out regarding Wootz steel and the Damascus swords in England, France and Russia