The Unknown Einstein

Bal Phondke

Vigyan Prasar

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To

Jayant Narlikar

A friend and A Beacon

—Bal Phondke

Foreword

Vigyan Prasar has been bringing out publications on a variety of topics of Science and Technology. Popular Science Classics, India's Scientific Heritage, Natural History, Health and Do-It-Yourself are some of the series that have evolved over the years. Our emphasis has been on bringing out quality publications on various aspects of Science and Technology at affordable prices. Further, Vigyan Prasar is putting in efforts to bring out publications in all major Indian languages for various target groups.

The present book, **The Unknown Einstein**, is by Bal Phondke, former Editor, Science Today, and Director, National Institute of Science Communication (Now National Institute of Science Communication & Information Resources, NISCAIR). Shri Phondke is a well-known science communicator and he writes both in English and Marathi. As the title indicates the book is an attempt to bring out the relatively lesser known yet enchanting facets of Albert Einstein's life and work. The author narrates many unknown anecdotes concerning Einstein's personality. The author tries to identify the persons and the circumstances, which influenced his thought process at various stages in his life. It is a highly readable book. In fact it reads like a story. Another attraction of the book is a large number of photographs that one does not find easily. There is no doubt that lot has been written about Einstein and lot more is being written in this year of World Year of Physics. Yet, one will find that this book on Einstein is with a difference. Everybody including those who do not have any science background will find the book interesting and readable. Any suggestion towards the improvement of the book will be welcome.

August 16, 2005
New Delhi

Vinay B. Kamble
Director
Vigyan Prasar

Preface

The Age is a very respectable newspaper from Melbourne, full of informative as well as entertaining items. It was getting to be Christmas time in 2004 and I was in that city editing the commemorative volumes being brought out by the Department of Atomic Energy in the relaxed frame of mind generated by the company of my grandchildren. Suddenly, a small item on the front page of *The Age* caught my attention. It said that Albert Einstein had invented a refrigerator and also held a patent for that.

To Einstein several new revolutionary discoveries have already and indisputably been credited. This was the first time he was being shown as an inventor. That was news to me. The item was titillatingly brief. It whetted my appetite for more information. I turned to the Internet and also visited the excellent public library that was conveniently located nearby. What I was able to unearth material that shed light on a number of facets of Einstein's personality as also his academic endeavours that have remained hidden from the public gaze. We know a great deal about Einstein's life and works. More is being written about it this year marking the centenary of his *annus mirabilis*. Yet, it appeared that there is a good deal that is unknown but enchanting.

That was the genesis of this book. Over the next couple of months, I did a lot of reading to find more and more of these unknown facts, which are now placed before the reader in a somewhat organised manner.

That it has taken this shape is due to generous help provided by some unknowingly and by others who knew what they were doing. Among the first category is Dr. Harshal Nandurkar, who always provides me with a fast and unlimited access to the Internet as also the tranquillity needed to do some concentrated writing. My friend Prof, D. Balasubramanian belongs to the other category. He went through the first draft and made some critical remarks that have helped me to improve upon the effort and smoothen out the rough edges.

When I approached Dr. V.B. Kamble of the Vigyan Prasar with a proposal for publication of this book, I had not anticipated such a ready and prompt acceptance. I am thankful to him for that, as also to Dr. Subodh Mahanti for letting the manuscript survive his editorial red pencil.

I have enjoyed getting to know *The Unknown Einstein*. I sincerely hope the reader does too.

– *Bal Phondke*

Prologue

As the countdown commenced heralding the end of the twentieth century, editors of *Time* magazine called upon its readers to vote the person, who, in their view, had left his or her indelible imprint on the sands of time during those hundred years. There were, quite naturally, a number of contenders, each of whom had made a mark in his or her chosen sphere of activity. Some had excelled in areas close to the heart of the common man. Others had led whole nations, nay the world, in bringing about a sea change in its social, economic and political fabric. Yet, by an overwhelming margin, readers from round the world chose Albert Einstein as the Man of the Twentieth century, such has been the fascination about his intellectual exploits.

That he, almost single handed, was responsible for changing mankind's perception of the structure of this universe, as also the manner in which it functions, is indisputable. Not that everyone understands precisely what he said about it. There are very few who can claim that distinction. Even so, everyone realises that Einstein did bring about a paradigm shift in our thinking.

That evokes an iconic image of Einstein in the minds of common folks. They always see him totally engrossed in his own dreamy universe oblivious to the ugly world that we all live in.

Was he really like that? Or was he, as Tony Philips has sketched, a harried young struggler who was trying to make two ends meet? Was he as a 'Technical Expert, Third Class', earning enough to provide for his growing family? Did he feel the same pressures that all young husbands have to withstand? Or was he really out of this world? A 'space alien' who came from some other planet that has no place for ordinary folks like us?

There is only one answer that is normally offered in response to questions like this. *We do not know.* Indeed we don't. About many facets of his personality. How could one single individual, who did not have the backing of an academic institution, who did not have a team of bright assistants to work for him, who did not have any sophisticated instruments at his disposal, so radically change mankind's perception of the material world? All in a single year? No wonder the man in the street holds him in awe. That is the reason that a number of, what Karl Kruzelnicki likes to call, mythconceptions have gained currency.

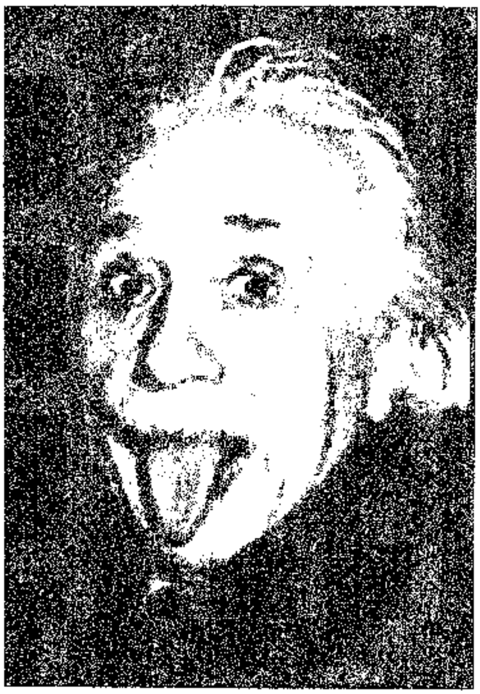
It is almost universally believed that notwithstanding his later intellectual prowess Albert Einstein was rather slow on the uptake during his childhood. He had no end of difficulties getting through the school curriculum. Countless dull students have found solace in the story that Einstein failed in his school final examinations.

These could perhaps be excused for not much is known about his personal life, much less about his early life. In fact, biographies giving some account of his personal life started appearing only some twenty years after his death. There can be no such excuse about erroneous beliefs regarding his academic pursuits. One just has to look at some quiz programmes to realise that everyone avidly thinks that the theory of relativity, profound though it is, is the only significant scientific contribution that Einstein made in his illustrious career. His Nobel Prize also is credited to his formulation of this theory. It is also thought that he said that time travel is possible. None of this is true. The facts state otherwise.

Even so, for all his accomplishments at a very young age, later in life, it should be remembered, he struggled mightily to produce a unified field theory, combining gravity with other forces of nature. He failed. Einstein's brainpower was not limitless.

That is another facet not known. *Not knowing*. It makes some researchers feel uncomfortable. It exhilarated Einstein: "The fairest thing we can experience is the mysterious," he said. "It is the fundamental emotion that stands at the cradle of true art and true science."

So the unknown should not be a deterrent or a *cul-de-sac*. On the other hand, it should act like a beacon and entice us into entering a whole new world, mysteriously enchanting. More so than time travel ever would be.



1
Was He A Failure?

No sooner a person achieves fame or celebrity status than all kinds of stories about his or her childhood start gaining currency. Most of these are laudatory suggesting that the individual had given advanced notice of his later prowess by showing precocious talent. There are a few, nonetheless, that hints at the contrary. They imply that in the early years the person was dull and dumb. Flattering or derogatory, all the tales are told with considerable aplomb as if the narrator had intimately known the luminary in his childhood and had an inkling of his future demonstration of brilliance.

Albert Einstein is no exception.

In his case though, there seems to be almost unanimous agreement that notwithstanding his later intellectual supremacy he was a rather dimwitted child. He could not even speak properly till he turned nine. Even then, he was a slow learner. He was all at sea with mathematics, a field in which he excelled subsequently. Some have claimed that he suffered from dyslexia, a learning disorder, and hence could not cope with the school studies. Several laggard school students have drawn solace from the legend that Einstein had failed his school final examinations. And although he somehow made it to the university later, his record there was dismal. That is the reason he could not get an academic position and had to be content with the post of a clerk at the Swiss patent office.

As usual there is a fair mixture of fact and fiction in all these anecdotes; little fact spiced up with a good deal of fiction.

Take, for example, the belief that he was unable to speak even when he turned nine. This is a misrepresentation. Even as a small boy Einstein was independent and thoughtful. According to family legend he was a slow talker at first, pausing to consider what he would say. That made people think that young Albert is unable to speak. This impression was compounded by his failure to attain fluency in German. Everyone in Germany, where he was studying, was expected to be proficient in that language, which was also Albert's mother tongue. Naturally, his teachers concluded that he is rather dense or a slow learner. But his sister Maja disagreed because she recalled "...even when there was a lot of noise, he could lie down on the sofa, pick up a pen and paper, precariously balance an inkwell on the backrest and engross himself in a problem so much that the background noise stimulated rather than disturbed him."

Albert's parents engaged a private tutor to give lessons when he was five. However, this arrangement came to an abrupt end. One day the youngster worked himself into a bad temper and threw a chair at his teacher. The tutor quit on the spot. But the early lessons in music given by his mother continued. The young boy actually became very fond of music. His instrument of choice was the violin. He began playing at the age of six with his mother who played the piano. Albert loved copying the work of Mozart and

Bach. His love of music later gave him a revelation. At the age of 13, Albert found that music held many of the same patterns responsible for mathematics, which he loved.

From 1885 when he was six years old he started attending a regular school. He went to "Petersschule", a catholic elementary school in Munich. His progress there impressed his mother. On seeing his report card one day she wrote to her sister: "Yesterday Albert received his grades, he was again number one, and his report card was brilliant."

When he turned ten, Albert enrolled in a new school, the renowned Luitpold Gymnasium, where the study of Latin and Greek was obligatory. As with all languages, learning a new vocabulary was essential. For Einstein the language lessons were tedious and irksome. He hated to memorize new words and grammatical rules, especially in Greek. Not surprisingly, his teacher of Greek believed nothing would ever become of young Einstein.

Albert loved geometry, which he began studying at the age of twelve. Philosophy was also very important to him because it was the study of the universe and the meaning of life. This encouraged him to look for more answers. He would have philosophy study every Thursday with a medical student named Max Talmey, who would join his family for dinner.

Schools in Germany in those days were run in a very rigid atmosphere. The teaching methods followed a strict disciplinary policy. That did not help matters either. Albert's innate curiosity made him disapprove this regimentation. He would always ask his teachers questions that they considered irrelevant or even irreverent. This unacceptable behaviour probably earned him the reputation of being a slow learner or one of rather dubious intellectual development. His differences with the teachers forced Einstein to search for knowledge at home. He began not with science, but with religion. He avidly studied the Bible seeking truth, but this religious fervour soon died down when he discovered the beauty of science and mathematics. To him, these seemed much more realistic than ancient stories. With this new knowledge he disliked class even more, and was eventually asked to leave Luitpold Gymnasium. "Your mere presence here undermines the class's respect for me," spat his 7th grade teacher, Dr. Joseph Degenhart. Degenhart also predicted that Einstein "would never get anywhere in life."

Looking back on those incidents he observed that, "It is almost a miracle that modern teaching methods have not yet entirely strangled the holy curiosity of inquiry; for what this delicate little plant needs more than anything, besides stimulation, is freedom."

One story Einstein liked to tell about his childhood was of a "wonder" he saw when he was four or five years old: a magnetic compass. The needle's invariable northward swing, guided by an invisible force, profoundly impressed the child. The compass convinced him that there had to be "something behind things, something deeply hidden. There was this huge world out there, independent of us human beings and standing before us like a great, eternal riddle, at least partly accessible to our inspection and thought. The contemplation of that world beckoned like a liberation."

"At the age of 12, I experienced a wonder in a booklet dealing with Euclidean plane geometry, which came into

The Nobel Diploma

A modern sculpture at Hershstrasse, Ulm, depicting Einstein's head with the equation $E = mc^2$

Einstein Fountain standing near the Town Hall in Ulm.
Water flows down Einstein's 'tongue'.

The Einstein Memorial in Bahnhopfstrasse in Ulm. This is near the place where Einstein was born.

Einstein Monument exactly at the site where Einstein was born. The original house was destroyed during the war. This monument was given to the city of Ulm by India. It was sculpted in Kolkata.

my hands at the beginning of a school year. Here were assertions, as, for example, the intersection of the three altitudes of a triangle in one point, which – though by no means evident – could nevertheless be proved with such certainty that any doubt appeared to be out of the question. This lucidity and certainty made an indescribable impression on me."

By the time he was thrown out of school at Munich he was 15. His family had also moved to Milan in Italy in an attempt to establish a business and earn a good living. Albert obtained a medical certificate that he was suffering from nervous breakdown, which necessitated his abstaining from school. So he joined his parents and did not go to any school for a full six months. He was glad to be rid of the inflexible schoolwork he hated and was free to explore the world on his own.

Following the wishes of his parents, Albert tried to enter the Swiss Federal Polytechnic (Eidgenössische Polytechnische Schule) at Zurich. Outside of Germany it was the best-known technical school in central Europe. Moreover, since it was in the German-speaking region of Switzerland there was no problem with the medium of instruction. Being a technical school, his parents thought that it would prepare him for a practical profession.

He arrived in Zurich in the autumn season of 1895. He was not entitled to take the entrance examination for the Polytechnic. Not only was he two years younger than the average candidate but also he had also not properly graduated from his school. He did not possess any certificate of high school graduation. Even so, an influential friend of his family helped him in getting permission to take the entrance examination.

The examination consisted of two parts: one, on general knowledge such as literature, history, fluency in German, descriptive natural sciences and the other, on mathematics, physics, chemistry, and technical drawing and freehand drawing. Einstein had no problems with the second part. He passed that part consisting of mathematics and natural sciences with flying colours. But the other part was too much for him. His results in languages and social sciences like history were very unsatisfactory. So he was declared to have failed the overall examination.

As expected, he was not admitted. He was disappointed yet he was philosophical about the outcome. He commented that, "Even though the examiners were patient and considerate, the examination made the gaps in my education painfully clear. I found it fully justified that I did not pass." Nonetheless, in view of his uneven knowledge and his tender age, the president of the Polytechnic was quite sympathetic. He attributed his ambivalent performance to his young age; he was only 16 years old, and his lack of proper high school education. He advised the parents to have their son attend the final grade of a Swiss middle school at Aargau.

The prospect of going back to gain a diploma at a middle school did not appeal to Einstein even though the lessons and final examination would not be quite as demanding as they were at the Luitpold High School. He would still have to take French but no more Greek and Latin courses.

The middle school would not give him sufficient credits to go on to a university, but would entitle him to go to the Polytechnic at Zurich. Einstein feared that going back to school meant the same kind of regimentation as in Munich. His fears were unwarranted. When he arrived at Aarau, which was not very far from Zurich, he was very pleasantly surprised. The Swiss school system was very liberally oriented, teachers encouraged students to think for themselves, and they were always available to them for discussion and counselling. Einstein blossomed under this system.

In September 1896 he successfully passed his A-levels in written and oral form. He obtained an overall grade of 5, which was considered good. In particular his grades in subjects like Algebra, Geometry and Physics were 6, the maximum and in Chemistry and Natural Sciences were 5, close to the maximum. Why did then the impression gain ground that he was a less than average student and barely managed to clear the school final examinations?

The answer can be found in the differences between the Swiss system of evaluation and its German counterpart. The Swiss A-levels were called "Matur"; it corresponds to the German "Abitur". Furthermore, the assessment scales for school performance (school grades) in Germany and in Switzerland were poles apart. While, the grade 1 in Germany implied excellent performance, under the Swiss system it was the poorest. Excellent performance was accorded grade 6 in Switzerland; the grade 2 (good) in Germany equalled grade 5 in Switzerland and so on. Naturally, his German friends and colleagues interpreted his school performance record in their own way. His grades of '6' in Mathematics and Physics were considered abysmally poor and those of '5' in Chemistry and Natural Sciences a shade better. The fiction was created whereas the fact was totally different.

His love for sciences was evident even at that early age. A kind of autobiographical essay, he wrote, when still at the School in Aarau, makes this amply clear. He said, "A happy man is too content with the present to think much about the future. On the other hand, it is young people above all who like to occupy themselves with bold plans....If I should have the good fortune to pass my examinations, I would go to the Zürich polytechnical school. I would stay there for four years in order to study mathematics and physics. I see myself becoming a teacher in these branches of the natural sciences, choosing the theoretical part of these sciences.

Here are the reasons that led me to this plan. Above all it is my individual disposition for abstract and mathematical thought...And then there is a certain independence in the scientific profession which greatly pleases me."

Those who think that Einstein was poor in languages would be surprised to know that this essay was written in French, a language foreign to him.

His grades at the final examination at Aarau were more than adequate to gain entry to the prestigious Polytechnic at Zurich. Even though he had missed a year in doing so he was, at 16, two years younger than the average student. In October 1896 he began to study at the Swiss Polytechnic. His ambition was to obtain the diploma of a subject teacher for mathematics and physics. In July 1900 he successfully finished his studies.

Around this time he recognized that physics was his true subject. Only there could he "seek out the paths that led to the depths." He also realized that he could never be an outstanding student. Fortunately his friend Marcel Grossmann had the conventional traits Einstein lacked. While Einstein worked in the library or the laboratory, Grossmann took excellent notes at the mathematics lectures, and gladly shared them with his friend before examinations. Einstein later wrote, "I would rather not speculate on what would have become of me without these notes."

Einstein's biographers have gone on record to state that he graduated with an undistinguished record. The fact is that his grade point score was 4.9 out of a maximum of 6. That may not qualify to be called 'excellent', or perhaps even 'very good', but is hardly 'undistinguished'.

These critics have also overlooked the fact that he had written his first scientific paper during these years. In his paper he referred to the wonderful experiments on electromagnetism, the propagation of light and heat, and the deformation of ether by electro-dynamic forces. He wondered whether a deformation of the ether would affect the propagation of waves and whether the effect would differ at right angles to the lines of force. His determination to seek answers to these questions led him later to elegant explanation of the photoelectric effect and eventually to the theory of relativity.

Despite such a college record, Einstein did not have an easy time finding a job. He mailed letters to many eminent scientists in Europe inquiring if they needed an assistant. He received no replies. This was partly because his former professors cautioned potential employers against him and also because they preferred a "genuine Swiss" before hiring a naturalized "paper Swiss." That Einstein came from Jewish ancestry added to the difficulties. Although 1901 was a year of turmoil for Einstein, it did have a good side.

His former classmate and friend Marcel Grossmann knew about Einstein's employment problems and could not understand how someone so talented could be in such a tough spot. Grossman's father knew Friedrich Haller, the director of the Swiss patent office, and put in a good word for him. When a newly created position opened at the patent office, Haller asked Einstein to apply for it immediately. Einstein did, was invited for an interview and accepted for future employment. In June of 1902 he started work at the office in Bern.

His job required him to transform written patent applications into clear and concise language. It meant studying many new ideas and picking the unique and essential features of an invention out of vaguely composed texts. Einstein's work at the patent office was neither well paid nor very demanding. However, it had one great advantage. The job left him some spare time for scientific investigations.

The so-called dull boy, having acquitted himself very well in the educational institutions, was ready to stun the world with his outstanding abilities.

2
Dollie and Johnny

Albert Einstein was a loner. By his own admission he liked to be left alone and was most happy when he was engrossed in his own thoughts. In an autobiographical essay titled 'The World As I See It' written in his mid-fifties, Einstein had expressed his personal attitude. He wrote, "My passionate sense of social justice and social responsibility has always contrasted oddly with my pronounced lack of need for direct contact with other human beings and human communities. I am truly a 'lone traveller' and have never belonged to my country, my home, my friends, or even my immediate family, with my whole heart; in the face of all these ties, I have never lost a sense of distance and a need for solitude..." This desire to be left to himself is probably the reason that his family life never came into the limelight. Barring a few biographies of recent origin not much is known about his parents or wives or children.

But no man is an island. Unbeknownst to one, one's thoughts and actions are influenced by one's near and dear ones. So it is with Einstein too. A number of members of his family have influenced his life and his thought processes at various stages in his life.

Even so, that part of his life had remained in the dark until the end of the 1980s. Around that time the collected works of Einstein were published. A number of manuscripts, documents, scribblings and letters saw the light of day for the first time. A biographical essay written by his sister Maja Wintler-Einstein also came to the attention of the world. This prompted a number of researchers to delve deep into Einstein's life and come up with some surprising revelations.

Einstein was born in Ulm, Germany on March 14, 1879. Einstein's parents – his father Hermann and his mother Pauline – were ordinary middle class Germans. They were Jews but uncharacteristically they were not overly devout. They did not impose any religious dogma or rituals on Albert. *"I was the son of entirely irreligious Jewish parents,"* he later recalled. They moved from Ulm to Munich when Albert was an infant. The family business was the manufacture of electrical parts. When the business failed, in 1894, the family moved to Milan, Italy.

His father did not do much to mould his son in any way. But he once bought him a compass to play with, while he was sick in bed at age 5. Albert was intrigued by the needle of the compass. He wondered what forces were at work to make the needle always point north. The compass made a deep and lasting impression on him.

His mother was responsible for inculcating in him love for music. She used to play the piano and young Albert would accompany her on the violin. Though he never had any formal training in music he was fairly proficient and preferred classical music, in particular composition by Johann Sebastian Bach. Even when he was at odds with his school studies he was very enthusiastic about his violin.

But if he was really close to anyone at that tender age, it was his sister, Maja. Two years younger than him, she was to remain his true confidant not only in childhood but also throughout his life. In a biographical sketch she wrote in the 1920s she has provided rare insight into Albert's emotional status as well as details about his parents, grandparents and other relatives.

Close as he was to his sister, on first seeing her after her birth he exclaimed, "But where are the wheels?" She also was at the receiving end of violent temper outbursts, which beset Albert in early childhood. It was during one such episode that he threw a ball at her head. On another occasion, he went as far as to attack her with a child's hoe. She was injured in the incident though fortunately it turned out to be not so grievous. Looking back at this episode Maja remarked jovially "it takes a sound skull to be the sister of an intellectual." This vicious temper disappeared when Albert entered school.

Maja also lets us know of the first reaction of their mother on seeing the newborn Albert. She was extremely shocked at the sight of the back of his head, which was large and angular. She feared that she had given birth to a deformed child. But the doctor reassured her. After a few weeks the shape of the skull was normal. The child was also very fat but very quiet. He would play by himself for hours thus sparing his mother from spending inordinately long time caring for him.

It is from Maja's account that considerable information about the Einstein family is available. Abraham Einstein, Albert's paternal grandfather, died in the prime of his life, and his grandson never knew him. He lived in Buchau on the Federsee (lake), and is said to have enjoyed a great and widespread reputation as an intelligent and upright man. His wife Hindel, Albert's paternal grandmother, died during her grandson's early childhood. Her intellectual powers, it seems, were not particularly outstanding. His grandfather on his mother's side was Julius Derzbacher, who took the family name Koch. He was from Jebenhausen, where he practised his trade as a baker

Albert's father Hermann was mathematically inclined. He would have liked to pursue studies in this or a related field. But his father's meagre finances, coupled with a rather large family, precluded that. So Hermann had to be satisfied with becoming a merchant. It appears that the mathematical potential, left fallow in the father, developed all the more strongly in the son.

Hermann was reasonably successful in his trade. Marriage with Pauline, who came from a relatively prosperous family, brought a degree of affluence to the Einstein family. Had it not been for his generosity towards his brother, Jakob, his son would have been well provided for and would have been able to pursue any course of study.

It was because of Jakob that the Einsteins moved to Munich from Ulm when Albert was hardly three years old. Jakob had qualified as an engineer. He also had an inventive bent of mind. He persuaded his brother to sponsor him in starting an electrical products business in Munich. Brilliant though he was academically, and innovative as an engineer, neither he nor Hermann had good business acumen. Consequently, not only Hermann but also his in-laws and some other relatives lost a fortune in the venture. In an effort to recover, at least some lost ground, the family moved to

Milan in Italy. But that move too turned out to be a misadventure. Jakob then went his way and took up a fairly lucrative job. But Hermann and his family had to live on very modest means.

Uncle Jakob later was to wield certain intellectual influence on young Albert. He introduced Albert to mathematical concepts that were beyond the level that he had learned at school. The concept of unknown variables intrigued Albert. Although he frequently made mistakes in mathematics, he began to understand the advanced concepts of algebra and geometry at a young age.

During all these vicissitudes of life, Albert had stayed away from the family over extended periods. That further made him go into his shell and become more of a solitary person. He did keep in touch with his sister but only through occasional and irregular correspondence.

It was while he was attending school in Switzerland that he developed very close relationships with two people, who were not members of his family. These associations lasted throughout his life. Both these were to have lasting impact on his personal life as also his career. One of these was his classmate Marcel Grossman. Their study habits, nonetheless, were quite contrasting. Albert did not care much for the classes. He would often give a miss to those and learn on his own by reading in the library or turning his hand at some experiment in the laboratory. Marcel, on the other hand, diligently attended the lectures and took copious notes. He would then pass on those notes to Albert who would use them to remain abreast of what was being taught in the classes. That, Albert had realised; was necessary for getting through the examinations. Einstein later wrote, "I would rather not speculate on what would have become of me without those notes."

In 1912, after his papers published during the miracle year had attracted attention worldwide, Einstein was invited back to the Swiss Federal Institute of Technology as professor. Here he rejoined his old friend Marcel Grossmann, now professor of mathematics. With Grossmann's help, Einstein studied the mathematical theories and techniques, which he found necessary for his work toward a new theory of gravitation. His friendship with Grossman was partly on the professional level as Einstein used his friend's mathematical prowess for giving his abstract ideas a more concrete shape. But the friendship also had a personal facet as Einstein, at difficult times in his personal life, always turned to Grossman for advice and counselling. But it was also during his polytechnic days that another friendship blossomed, which was to change his life for better and for worse. Quite literally. The person concerned was Mileva Maric, a Serbian classmate of Albert.

Mileva was born just before Christmas in 1875. Her parents doted on her and nicknamed her "Mitza." She limped because of a displaced hip, a birth defect unusually common in that region. As a youngster, she showed a gift for mathematics and languages, painting and music. Mileva's family was fairly wealthy, and she received superior schooling.

When Mileva turned 15, her father was able to obtain special permission for her to take classes at an all-male prep school. There she normally kept to herself, and earned the highest grades in both mathematics and physics. Mileva's father's influence could not go beyond a point. So it was not possible for her to continue her higher studies. Middle

Europe at that time constituted a very conservative society that did not look kindly on women taking up courses in sciences. These were considered to be male preserves. Her contemporary, the legendary Marie Curie, also had to face similar problems in very liberal France. Marie was reluctantly tolerated by those who controlled the groves of academe there only because of her marriage to Pierre Curie, who was a highly respected professor of physics. To continue her education, Mileva had to go to Zurich, one of the few European cities with a university that accepted women.

In the summer of 1896, she began studying medicine. However, shortly thereafter, by October that year, she switched to the university's Technical Institute, the ETH. She was nearly 21, and only the fifth woman to be accepted by the ETH. One of her classmates was Albert Einstein. He was only 17, a boy barely worth noticing. Her first year was an outstanding academic success compared to the modest performance of Albert. She outperformed many of her male colleagues and stood first in sciences. But laws of physics tell us that polar opposites always attract each other. These laws probably governed the interaction between Albert and Mileva.

For the first semester of the second year, Mileva decided to go to Heidelberg. The separation ironically brought the two young people together. They exchanged long passionate letters. While she described, in great detail, the satisfactions of her studies, Albert called her a "little runaway," telling her to "come back soon."

When she returned in the spring of 1899, all formality between them had disappeared. He called her 'Dollie'. She responded by naming him 'Johnny'.

They embarked on an almost 'filmy' love affair. Her parents were tolerant, knowing that Mileva's marital prospects were not very bright, what with her physical handicap and also her exceptional intelligence. His parents, on the other hand, opposed the relationship vehemently. They raised all sorts of objections and found every kind of fault in her. 'She is too old', which was true. But love does not take into account the age difference either way. 'She is too bookish'. That was also true; but that was what Albert had found most attractive. 'She is lame, she is not Jewish, she is a foreigner, a Serbian.' his mother, Pauline Einstein, offered stern and parental advice. It is said that she told Albert, "If she gets a child, you'll be in a pretty mess." But none of these made any impact on the young lovers. In fact, the greater their opposition, the more Mileva protected Einstein, eventually placing his interests before her own. He demanded all her time. So, she sacrificed her studies as well as her friends. While he managed to clear his exams and secure his diploma, she failed. Still, when he could not find work despite his graduation she supported him emotionally, and financially as well. It was entirely due to her that he did not lose heart and was able to withstand the tribulations of that difficult period in his life.

Her selfless devotion, however, was not reciprocated in full. As long as Albert lived with her in Zurich his love for her remained unabated. But then he had to go for a while to his family in Milan. That seemed to have cooled his ardour. Though he continued to meet her occasionally, he appeared lukewarm. By then Mileva had become pregnant. That news also did not enthuse him much. The mental agony that she underwent during this period could not help her in her studies. She failed yet again. Her family too had become impatient with her. She appeared to be on her own with no one to offer her any solace or support. She continued to urge Albert to get married. But he kept finding some excuse or the other to postpone tying the knot. Her pregnancy was advancing by the day. She gave birth to a baby girl, Liserel, in January 1902. She was in Novi Sad (in present day Yugoslavia) at the time. She communicated the good news to Albert without eliciting any response from him. He did not go to see his first-born.

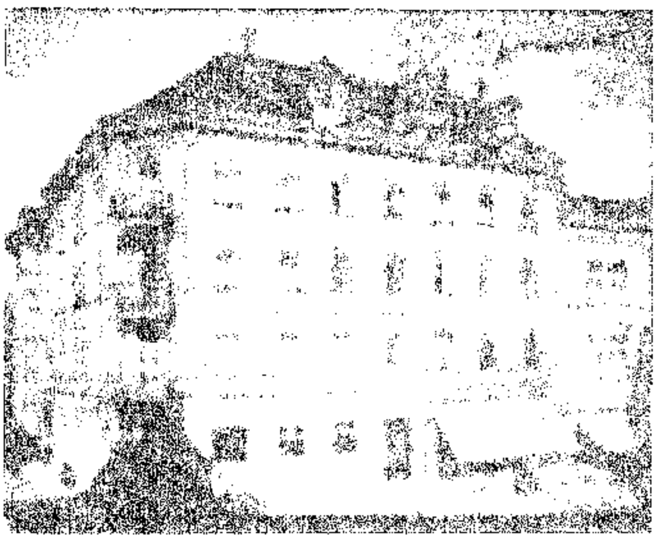
There is some mystery about this daughter. Neither Albert, nor Mileva ever spoke of this child, not even to their closest friends. Liserel seemed to have vanished. She was never heard of again, nor are any pictures of hers available. The public became aware of this illegitimate child 30 years after Einstein's death. Her existence first came to notice in 1987 with the first volume of his collected papers. What happened to Lieserl, and why didn't her parents take her to Switzerland and allow her birth to become legitimate? Some say she lived in Serbia, or had been given up for adoption. But an American writer Michele Zackheim has done some research and produced a book, *Einstein's Daughter: The Search for Liserel* in which she provides her personal theories. Zackheim's book states the belief that the daughter was retarded, possibly having Down's syndrome. During that time, it was not considered worth educating such a child. She also states that the daughter had been taken to Mileva's parents home in the Vojvodina region of rural Serbia. Zackheim believes that this is where Lieserl died before the age of two with scarlet fever. She believes the death occurred on September 15, 1903, ironically during a solar eclipse. According to another theory, Mileva, who could not cope with her by herself, gave her up for adoption. Even she did not care to know of her whereabouts subsequently. Whatever the reality, the truth is that Mileva lost her. She could not come to terms with that fact and her attitude towards Albert was tinged with that perspective.

Around that time Albert had landed the job at the patent office in Bern. Mileva joined him there. The relationship took a new turn and blossomed again. On January 6, 1903 Albert and Mileva were married in a civil ceremony.

Their life together was, however, no great joy. Albert was at work six days a week. He also spent all his spare time working on his theories. Mileva had to take care of the house, their daughter and also look after his material comforts. She had given up her studies. Any possibility of having a scientific career was now remote if not non-existent.

The next year she gave birth to their second child, a boy, Hans Albert. But that failed to bring much joy to the family. Albert and Mileva continued to drift further apart. At one time Albert had confessed to his friend that marriage to Mileva could have been the best thing that happened to him. He found in her an intellectual equal with whom he could engage into meaningful dialogue. She could understand the mode of working of a scientist. Nonetheless, the moment the world discovered the scientist in him, it brought discord on the family front.

That was the year 1905, Albert's *annus mirabilis*. He produced outstanding research papers one after another. With the publication of the Special Theory of Relativity his fame and standing grew in an unprecedented manner. There were many more demands on his time. He could not find any to devote to his harassed wife or family. The dialogue had all but vanished.



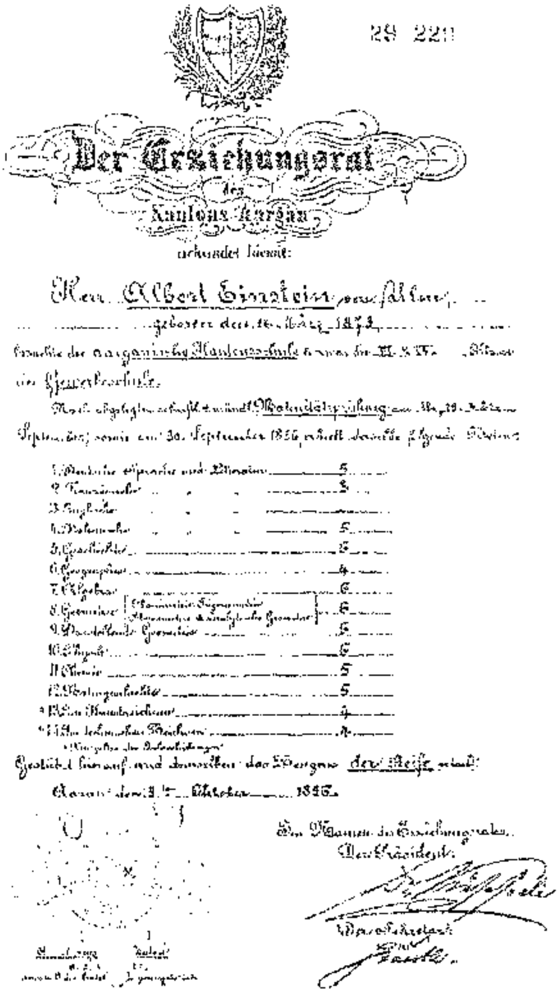
House at Ulm where Einstein was born

Einstein at the age of four


Einstein's parents: Harmann and Pauline

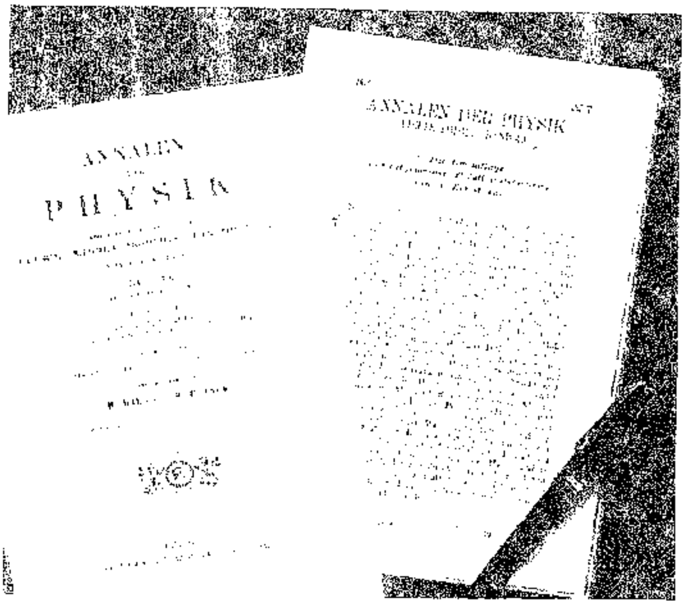
With sister Maja

Einstein with classmates at Aarau



Einstein's school certificate

At the Swiss Patent Office

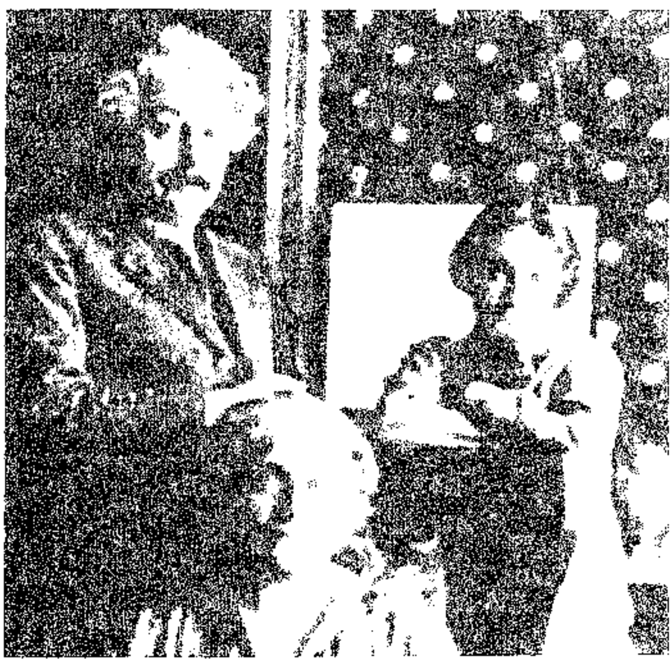


The Annalen der Physik *paper on relativity*

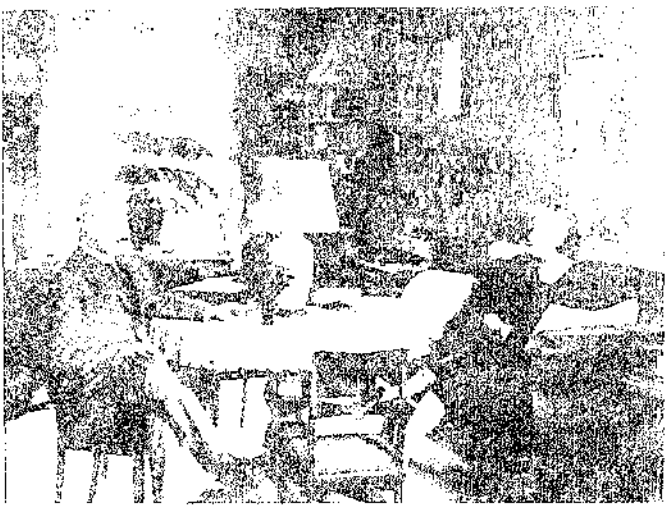
With first wife Mileva

Mileva with Hans Albert and Eduard

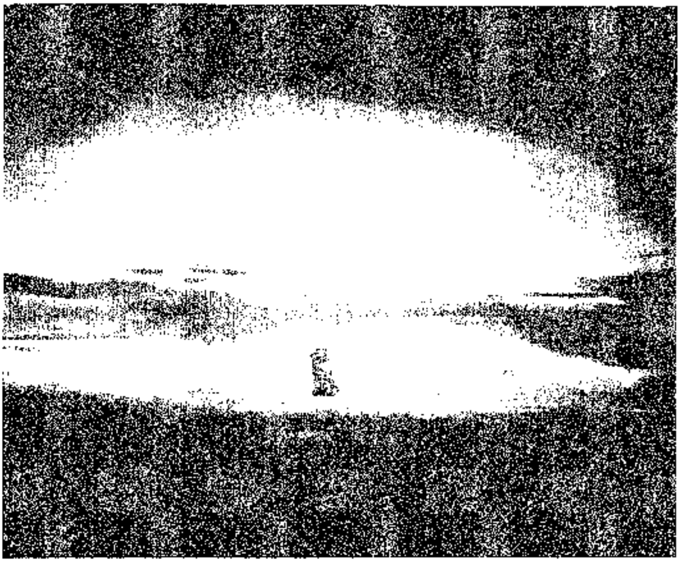
With second wife Elsa



With Elsa and Margot



At home in Berlin with Elsa



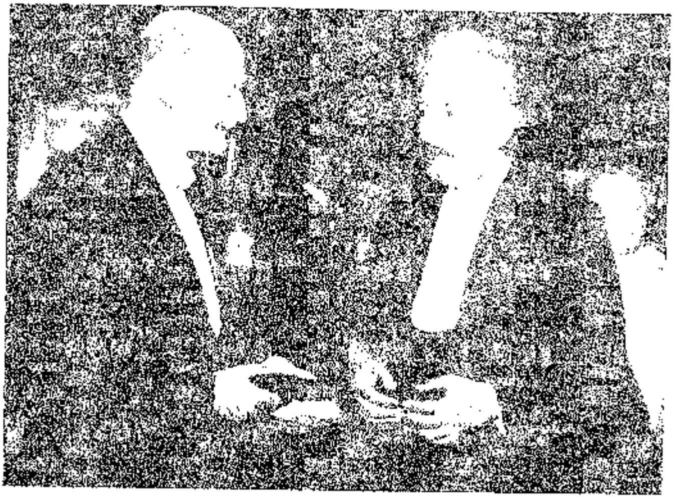
Detonation of an atomic weapon

At Princeton

At the blackboard

Cycling at Princeton

A life-long passion



With Max Planck

With Leo Szilard

With officials of Hebrew University

With Elsa at Princeton

The job at the patent office had become an anachronism. His heart was never in it in the first place. Now with offers to become a full time academic he did not have any hesitation to resign the post. He became a professor in Zurich. Though that gave a boost to his career, the marriage was on the rocks. Albert also met his cousin Elsa there and fell in love with her. That enraged Mileva. So to buy peace Albert agreed to go on a vacation.

That was the last joyful time the two had together. Soon their third child, a son, Eduard was born. He was a problem child right from the beginning and became more so as he grew. By then Albert was constantly on the move. He left Zurich for a job in Prague. He did not stay there for long and came back to Zurich.

But the fame and attraction of more distinguished positions had brought about a distinct change in Albert's demenour. So, when he was offered a prestigious position in Berlin he immediately grabbed it. That meant yet another move. Mileva had got tired of this constant uprooting. Even so, she reluctantly agreed to accompany Albert. Perhaps the fact that Elsa resided in that city had persuaded her to move.

But life in Berlin was far from a bed of roses for both of them. The year was 1914 and Germany had declared war on Britain and France. Einstein, pacifist that he was, found Germany's increasing belligerence and military adventurism distasteful. At other times he might have kept his thoughts to himself. But now that he was in limelight, he did not have that luxury. Moreover, once he found that his views are sought by many he grew in confidence and decided to go public. He denounced the German position. But that made several people angry. They thought that he was against

Germany per se and hence a traitor. His being a Jew did not help matters either. Even some intellectuals, including some of his colleagues, openly denounced him.

These tensions at the workplace and in the social milieu inevitably had their impact on the domestic front. Mileva's patience was wearing thin. Finally, she could not take it any more. She took her sons and went back to Zurich imploring Albert to accompany her. He did not, though he promised to return soon.

That promise, alas, was not kept. Instead Albert moved in with Elsa. Mileva kept on waiting forlornly. The ambiguity in their relationship, however, could not be sustained for long. In 1916 Albert sought divorce from Mileva. Despite Albert's attitude towards her in the immediate past, that demand came as a rude shock to her. She could not quite accept that the relationship had broken down irrevocably. She fell ill and had to be hospitalised. The decision on her part had to wait. She tried in every which way, over the next couple of years, to bring about reconciliation but to no avail. Finally, she agreed to grant Albert the divorce, on condition that he provides for her and the sons. Curiously, one of the clauses in the settlement devolved around the cash he would receive in the eventuality of his getting the Nobel Prize. His scientific accomplishments were of such magnitude that there was no doubt in anyone's mind about his joining the list of illustrious laureates. The only question, if at all there was one, was when would that distinction be conferred on him. Mileva demanded that the cash should go to her and surprisingly Albert did not demur.

His later family life was sedate. He married Elsa and had a daughter Margot. Even after that marriage Albert did have an affair or two. But Elsa was more tolerant, or perhaps tactful, so much so that she did not allow these *affaires-de-Coeur* to result in any discord in the marital relationship.

Einstein was awarded the Nobel Prize in 1921. Even before that Albert was globetrotting lecturing on his theories. He could not even attend the Nobel Prize award ceremony as he was in Japan at the time and had made several prior commitments. That was also the time when Germany was going through a very difficult period. The economy was in shambles and a great social and political upheaval was in the offing. Anti-Semitic sentiments were now expressed in a very overt and vociferous manner. The Nazi party was in the ascendance. Neither Albert's anti-fascist views nor his Jewish background could be tolerated. His life was in danger. So when the opportunity came Albert, with Elsa and Margot, left Germany for good and sought asylum in the United States. He eventually became a citizen of that country and settled in Princeton.

Life in the States was certainly more peaceful than in Europe. Perhaps Albert had mellowed with age. Though he continued to produce some seminal work, his objective of producing a theory that brought about a grand unification of all the fundamental forces could not be materialised. He kept trying in vain till his last.

Elsa died in 1936. The devoted daughter Margot and the faithful secretary Helen Dukas took care of the now meagre demands of the lonely widower. But Mileva's life after the divorce was utter misery. The money she got out of settlement did not last long. Europe at the time was financially on the brink of ruin. Eduard's schizophrenia had reached such a proportion that the medical expenses burnt a big hole in the kitty. In the last stages she did not even have a permanent roof on her head.

It is perhaps easy to find fault with Albert for his ill treatment of Mileva. His frequent extramarital dalliances could also be looked upon as a blot on his character. Still, in the social atmosphere of Europe in those times such situations were not uncommon. One would like to expect someone like Albert Einstein to be different from the rest of the crowd. After all, everyone looked up to him as a role model. Nonetheless, whether those expectations should extend to his personal life and behaviour is debatable. What is not would be his conduct in matters scientific.

That is why, whether Mileva made a significant contribution to his scientific exploits and whether she was denied her rightful credit for the same are issues that have generated heated discussion. The public television channel in the United States presented a lively programme on this very issue in 2002. The arguments in favour of Mileva were that she was a very capable intellectual, a fact that Albert himself had acknowledged before his disaffection with her took root. Since his work essentially involved thought experiments and theoretical discussions, she could very easily have participated in them. There are also tantalizing clues in the letters Mileva exchanged with Albert, and with their friends. Some supporters of Mileva cite the ease with which Albert agreed to give all the money he would receive as a part of the Nobel Prize to her. Was it not to assuage the guilt complex that had bothered him, they ask.

There are several credible scientists who believe Mileva may have collaborated on at least some of the 1905 papers. Among her supporters was Abram Joffe, a respected member of the Soviet Academy of Sciences. From 1902 to

1906, Joffe was working in Munich as an assistant to W. C. Röentgen. Since Röentgen was a member of the *Annalen der Physik* editorial board, Joffe could easily have seen the original manuscripts of the 1905 papers. Unfortunately, Joffe died in 1960, before anyone had much interest in Mileva. But there is at least one printed report in which Joffe declared that he personally saw the names of two authors on the 1905 papers: Einstein and Marity (a Hungarianized form of Maric).

On the other hand, Mileva never publicly sought any credit for those works; not even when she had fallen on bad times and Albert was not providing any succour. She had ample opportunity to do so. But she had maintained complete silence on that issue. The possibility that Mileva could have been an equal associate was first aired late in the 1980s when *The Collected Papers of Albert Einstein* were being readied for publication. That monumental work involved going through a good deal of correspondence, some of which was personal. That is when Mileva's story first saw the light of day. By then all the players in that drama had left the worldly stage. So, one had to rely totally on written records. The editors of the *Collected Papers* did just that but could come to no definitive conclusion. They simply claimed neutral territory by stating, "We have found no documentary evidence that would demonstrate her active participation in his scientific work, but we do not endorse the view that she took no part in it. We simply do not know."

In February 1990, members of the American Association for the Advancement of Science convened to debate the subject of Mileva Mâric's possible collaboration on the 1905 papers. The group could not reach a consensus.

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Annus Mirabilis

Albert Einstein and Relativity have become synonymous; so much so that almost everyone believes that the theory of relativity is his only important contribution to humankind's knowledgebase. It is also believed that he was awarded the Nobel Prize in Physics in the year 1921 for promulgating this theory.

None of this is true. No doubt the theory of relativity stands out among his phenomenal contributions. However, in a single year, 1905, Einstein published as many as five papers in the most prestigious scientific journal of the time, each of which has brought about a sea change in our understanding of the universe. Each of these papers was worthy of a Nobel Prize on its own merit. Each of these concerned a different natural phenomenon apparently unrelated to others. And he accomplished all this when he was only 26, without even a doctoral degree to his credit. At the time he was working totally on his own without the benefit of being a member of a scientific institution. He had barely managed to land himself a job as a clerk in the patents office in Berne, the capital of Switzerland. He later went on to enlarge his canvas and apply the basic tenets of relativity to the entire cosmos to advance our knowledge of the force of gravitation, the fundamental force that not only gave birth to the universe but also continues to hold it together.

The year 1905 has rightly been termed *Annus Mirabilis*, the Miracle Year. For that year forever altered our understanding of the way this universe came into being and the way it functions, thanks to Albert Einstein.

It all started in March of that year when the little known patent clerk made bold to write a paper with an innocuous sounding title and send it to the leading physics journal of the time, *Annalen der Physik*. He probably chose that journal because it was published in German, a language most familiar to him. Also, he had seen it mentioned often in the literature supporting patent applications that he had to read as a part of his job.

Publication of a research paper follows a different process than the one for publication of an article in a newspaper or a short story in a magazine. The latter gets published if the editor in charge of that section approves of the unsolicited contribution. In the case of a research paper, the editor does not take the decision entirely by himself. He seeks help from others well versed in the particular field. Though usually a scientist himself, the editor may not be a specialist in the same field. He, therefore, refers the paper to two or three experts in the specific field, the peers.

This process, known in the scientific circles as the peer review, has withstood the test of time and is respected the world over. Publication of a paper in a peer-reviewed journal carries much greater weight. Scientific journals follow this convention quite rigorously. The editor bases his final decision on the comments and recommendations of the referees. The identity of the peer referees is not revealed to the author. The referees are thus able to voice their criticism quite freely. In turn, they enable the editor to take an objective decision. Instances, where papers submitted even by Nobel laureates are rejected because peers have found serious flaws in them, are not uncommon.

This process, of course, takes significant time. That is why detractors of Einstein have wondered how his papers saw the light of day so soon after submission, especially since he was an unknown entity then. They have found out that his papers were not submitted for peer review. They have latched on to this piece of information to support their contention that there is something quite fishy in the process and have vociferously suggested that Einstein was a hoax.

They have, of course, jumped to premature and erroneous conclusions. The fact is that the editor-in-chief of *Annalen der Physik* in those days was Max Planck, a very renowned physicist who had already attained very high stature. He himself had brought about a paradigm shift in thinking in the field of atomic physics by proposing the quantum theory. It was his nature to encourage publication of radical or outlandish views in order to let fresh air flow in. When Einstein's first paper on photoelectric effect landed on his desk he immediately saw that ideas totally off the beaten track were expressed in a very cogent manner. Being an expert in the field himself, he was able to gauge the merit of that paper and to take the decision to publish the paper on his own. The time delay was thus avoided. His subsequent papers that year were also not subjected to peer review. The decision to publish was made exclusively by either the editor-in-chief, or his co-editor Wilhelm Wien — both certainly 'peers' beyond doubt. Both of them were later to win the Nobel Prize in Physics themselves. Also, at the time there was a policy that allowed authors much latitude after their first publication. In a recent editorial in *Nature*, it was stated that "in journals in those days, the burden of proof was generally on the opponents rather than the proponents of new ideas."

This is not the only instance when the time-honoured process of peer review was given a go by. Another groundbreaking paper in recent times also was published in *Nature* without any peer review. This was the paper by Watson and Crick describing the structure of DNA, which has ushered in the age of biotechnology, in which we are living. John Maddox, chief editor of *Nature*, stated that "the Watson and Crick paper was not peer-reviewed by *Nature*... the paper could not have been refereed: its correctness is self-evident. No referee working in the field could have kept his mouth shut once he saw the structure". The editors accepted the paper upon receipt of a very brief covering note from influential physicist and Nobel laureate William Lawrence Bragg, which contained just one word, "Publish".

So what was so seminal in Einstein's paper that Planck was persuaded to bypass the peer review and have it published without delay?

It was known that when light was shone on certain substances, the substances gave out electrons. Also, only the number of electrons emitted, and not their energy, was increased when the intensity of incident light was increased. This was at odds with the classical electromagnetic theory, based on Maxwell's equations and the laws of thermodynamics. This theory had assumed that electromagnetic energy consisted of waves propagating in a hypothetical, all-pervasive medium called the luminiferous ether, and that the waves could contain any amount of energy no matter how small. Despite intense efforts, however, nobody could show the existence of ether. Moreover, when waves strike any substance the energy of the liberated electrons ought to be proportional to the intensity of light. The observed phenomenon was at variance with this expectation. In 1900, Max Planck had suggested that light was made of particles called "light quanta." Still, even his theory could not explain this particular or even some other observed electrical effects of light such as fluorescence Einstein went far beyond and advocated that light has a dual nature, with properties of both waves and particles. It was a radical idea. He hypothesised that the energy carried by any light particle, called a photon, is proportional to the frequency of the radiation. His revolutionary concept could account for all the observed phenomena very neatly. Alongside Max Planck's own hypothesis, and Niels Bohr's later work on quanta of matter, Einstein's work anchors the most shocking idea in twentieth century physics that we live in a quantum universe, one built out of tiny, discrete chunks of energy and matter. Virtually no one accepted Einstein's proposal until a decade later when the American physicist Robert Andrews Millikan experimentally confirmed the theory. This theoretical exposition was cited as a vital contribution to the advancement of physics when Einstein was awarded the Nobel Prize sixteen years later.

The world was still reeling with the impact of the shock waves generated by Einstein's explanation of the photoelectric effect when Einstein sent in another two papers in quick succession. The May and June issues of the journal contained these papers, which dealt with random motion of atoms, which occurred all the time. This was an extension of Einstein's doctoral thesis, which dealt with 'Determination of Molecular Dimensions'. When the dissertation was presented first to the University of Zurich in 1901 it was rejected because it was considered 'totally incomprehensible'. Undaunted, he did some additional work and completed it on 30 April. 1905. He resubmitted this enlarged and neater version to the university in July of that year. He received news of its acceptance and award of the degree in August by which time he had sent in his most celebrated paper expounding his groundbreaking concept of relativity.

But when he completed his doctoral thesis he was still preoccupied with random atomic motion. In 1827, the botanist Robert Brown observed under the microscope movement or motion of plant spores floating in water. The particles appeared to be rushing about randomly all the time. This weird phenomenon was already explained in terms of the random motion of molecules "hitting" the spores. But the first satisfactory theoretical treatment of the Brownian motion was made by Albert Einstein in these papers. Einstein's theory enabled significant statistical predictions about the motion of particles that are randomly distributed in a fluid. These predictions were later confirmed by experiment.

The net result was a proof that atoms actually exist – still an issue at that time – and the end to a millennia-old debate on the fundamental nature of chemical elements. The invisible atoms in water bounce around the pollen grains kicking them like footballers kick a ball. The discovery paved the way for other scientists to identify methods for measuring the sizes of atoms; on the basis of how fast they move.

Next came the papers that made the name Einstein known beyond the confines of theoretical physics. This was the special theory of relativity. For a paper containing such world-shattering concepts the title was rather unassuming. "On the Electrodynamics of Moving Bodies".

To explain the photoelectric effect Einstein had assumed light to be particulate in nature. But even then he had postulated light to have a dual nature. Now to explain another natural phenomenon concerning light, he employed its other face. He treated light as continuous stream of waves. The interaction of radiation like light and matter had intrigued scientists for a long time. Despite concentrated attempts by some of the stalwarts a comprehensive explanation had eluded the scientific community.

Newton and Galileo's theoretical foundation had portrayed the universe as a mechanical entity. So laws of mechanics ruled supreme. One of these was the principle of relativity. According to this principle mechanical processes could never show any difference between an apparatus at rest and an apparatus moving at constant speed in a straight line. Objects behave the same way on a uniformly moving ship as on a ship at the dock. Came Maxwell and his electromagnetic theory and an exception to this rule was found. The principle of relativity should not apply to light as per this theory. Measurement of the speed of light should clearly exhibit the effects of motion. But reality failed to match this prediction.

So Einstein came up with new theoretical computations to reconcile the apparent conflict between these two theories. For this purpose he made two crucial assumptions. One, the principle of relativity was applicable to all phenomena without any exception. And two, the velocity of light in vacuum was a universal constant; it did not change according to the frame of reference of the observer.

In 1887, two American scientists, Albert Michelson and Edward Morley, had conducted the now famous experiment to see if motion had any effect on the speed of light. The apparatus they used consisted of a massive stone block with mirrors and crisscrossing light beams. It was capable of giving an accurate measurement of any change in the velocity of light. Michelson and Morley expected to see their light beams shifted by the swift motion of the Earth in space. To their surprise, they could not detect any change. It is debatable whether Einstein paid heed to this particular experiment. But his assumption that the velocity of light in vacuum is an universal constant did allow him to come up with a neat explanation of the apparently conflicting information. To bring about the reconciliation between the various theories and actual observations, he thought that one had to change one's basic ideas about time and space. He set up new equations that showed that speed of movement affected all the three fundamental entities, length or volume, mass and time. As the speed of motions of an object increased its length diminished in the direction of the motion, mass increased, and time underwent dilation. He was thus able to provide a consistent and correct description of physical events in different inertial frames of reference without making special assumptions about the nature of matter or radiation, or how they interact.

In another month he came with extension of this radical theory to come up with even more radical manifestation of his tenets. He proved that energy and matter are linked in the most famous relationship in physics: $E=mc^2$. The energy content of a body is equal to the mass of the body times the speed of light squared. At first, even Einstein did not grasp the full implications of his formula, but even then he suggested that the heat produced by radium could mark the conversion of tiny amounts of the mass of the radium salts into energy.

Independent confirmation of his concept was slow in coming. Then, in Paris in 1933, Irène and Frédéric Joliot-Curie took a photograph showing the conversion of energy into mass. The photograph showed sudden appearance, seemingly out of thin air, of two particle beams that curved away from each other. This phenomenon, now known as pair production, occurs whenever a gamma ray photon, which is but a quantum of light, changes into mass in the form of two freshly created particles, an electron and a positron. Since they carry charges equal but opposite to each other they fly away from each other at speed.

The reverse phenomenon was also observed soon in England. John Cockcroft and E.T.S. Walton, who had constructed a massive particle accelerator, were able to break apart an atom. The resultant fragments had slightly less mass in total than the original atom, but they flew apart with great energy.

Newton started with three axioms, what are now known as Newton's laws of motion. From this simple beginning he went on to deduce the universal law of gravitation. That allowed him to give a detailed and fairly accurate explanation of the dynamics of motion of all the heavenly bodies as well. As the apparatus for observation of these motions became more sophisticated several phenomena, which seemed to defy Newton's deductions came to light. So Einstein had a fresh look at the whole situation *ab initio*. He started with only two maxims – that of the principle of relativity and the constancy of speed of light. He was able to have a much deeper insight with far ranging applications.

That was the culmination of his unprecedented outburst in such a short span of time. Those six months, March to September of a single year, saw an obscure patents clerk catapulted to fame as the leading light of physics, the likes of whom the world had never seen before or since. No wonder the year 1905 has been termed *Annus Mirabilis*, not only for Einstein but also for entire humankind.

Although Einstein's five papers were published in a single year, he had been thinking about physics, deeply, since childhood. "Science was dinner-table conversation in the Einstein household," explains Peter Galison, Professor of Physics at Harvard and a science historian. Albert's father Hermann and uncle Jakob ran a German company making such things as dynamos, arc lamps, light bulbs and telephones. This was high-tech at the turn of the century, "like a Silicon Valley company would be today," notes Galison. "Albert's interest in science and technology came naturally."

Still, that was not the only year in which he was productive. He continued to make seminal contributions over the next three decades and more. They were no mean contributions either. However, they paled into relative insignificance in comparison with the brilliance of his output during the miracle year. It is like the forties and fifties that Sachin Tendulkar scores do not capture anyone's imagination because fans are accustomed to seeing him make centuries.

Nonetheless, two of his subsequent exploits do stand out. One of them involved application of his tenets of relativity to the phenomenon of gravitation. While formulating the Special Theory of R lativity he had looked at the electrodynamics of objects that moved only along a straight line and at constant speeds. The objects neither veered left nor right, neither up nor down; nor did they vary their speed.

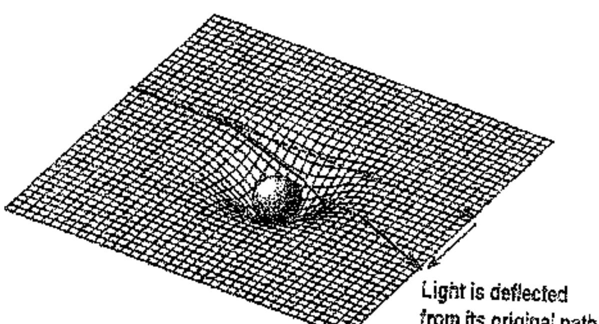
He now extended his concepts to take into account those objects, which moved at varying speeds and also along a complicated curvilinear trajectory. He thus encompassed almost all the objects in this universe. This is now called as the General Theory of Relativity because it is not restricted to a particular group of objects. He began by enunciating the principle of equivalence, a postulate that gravitational fields are equivalent to accelerations of the frame of reference. For example, people in a moving elevator cannot, in principle, decide whether the force that acts on them is caused by gravitation or by a constant acceleration of the elevator.

In general relativity Einstein shows that matter and energy – all the "stuff" in the universe – actually mould the shape of space and the flow of time. What we feel as the "force" of gravity is simply the sensation of following the shortest path we can through curved, four-dimensional space-time.

Before 1905, when Albert Einstein published his theory of special relativity, most people believed that space and time were as Sir Isaac Newton described them back in the 17th century: Space was the fixed, unchanging "stage" upon which the great cosmic drama unfolded, and time was the mysterious, universal "clock in the sky." Even today, people commonly assume that this intuitive sense of space and time is correct. It's not.

Einstein's special theory of relativity published in 1905 and the general theory of relativity published in 1915, painted an entirely different and mind-bending picture. Space itself is constantly being warped and curved by the matter and energy moving within it, and time flows at different rates for different observers. Numerous real-world experiments over the last 100 years indicate that, amazingly, Einstein was right.

To understand Einstein's view of the space-time continuum, consider a tautly stretched trampoline. It lies flat as long as it is empty. But the moment an object is placed on it that spot sinks causing a dimple or a curved space. If an elephant stands on that trampoline it would sink in to a greater extent than when an ant climbs on the same. If one now approaches the elephant one would reach the edge of that dimple, the curved surface of the dent the elephant has caused. The gradient there would cause an increase in one's speed. Compared to the speed with which one is able to move on the flat surface the speed now would be greater. That gives a feeling of being attracted towards the massive

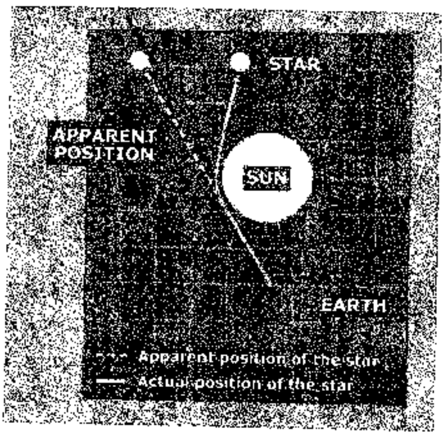


Space Time Curvature

object. The space-time continuum can be seen as that stretched trampoline. Thus any object would cause a sinking dent in that fabric; the more massive an object the greater would be the depth of that crater and hence the stronger would be the force of attraction. That is what gravity is, said Einstein.

As one can easily see, this is a radical vision: space is no longer the box the universe comes in; instead, space and time, matter and energy are, as Einstein proves, locked together in the most intimate embrace. With this our view of our universe was altered for all time to come.

Still, confirmation of Einstein's theory was not easy. How does one 'see' that stretched trampoline of space-time, much less the 'craters' caused by massive objects? The evidence had to be found indirectly by testing some of the implications of this new insight. That became available through the efforts of astronomer Arthur Eddington. In 1919, Eddington tested Einstein's idea during a solar eclipse, when he was able to measure the position of stars in the direction of the Sun.

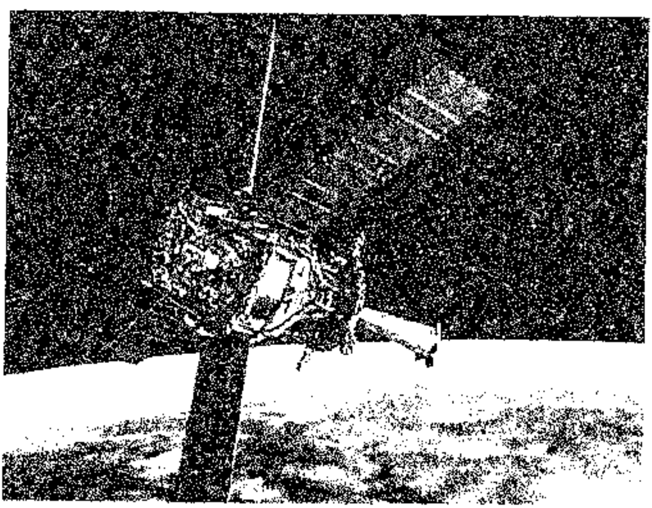


Eddington's Experiment

Eddington found that the daytime and night-time positions of the stars appeared to be different! Why? The Sun's mass caused space to bend, and starlight followed the path of bent space. This experiment proved that Einstein's light-bending prediction was right.

However, that is still an indirect proof. A more direct one is now being sought. Towards this objective NASA has sent out a probe called simply as *Gravity Probe B* or *GP-B* for short.

According to Einstein, Earth makes a dimple in the space-time around it. Because Earth spins, this "dimple" is twisted into a shallow vortex. *Gravity Probe B* is orbiting Earth, right now, in search of these distortions. *GP-B* senses the distortion using gyroscopes. There are four of them onboard the spacecraft. Francis Everitt, principal investigator for *GP* and a professor at Stanford University, explains,



Gravity Probe-B Satellite in Orbit

"Gyroscopes moving through curved space-time will gradually change their direction of spin (*i.e.* tilt) with respect to the stars. *GP-B* will measure that tilting motion with extraordinary precision and from that measurement we can calculate the structure of space near the Earth."

The ramifications of his special theory of relativity were indeed shocking insofar as they were completely in contrast to our normal experiences. Dilation of time or contraction of space as a consequence of movement was not easy to comprehend even for specialist physicists. Einstein himself had several periods of doubt. He has gone on record to say, "When the Special Theory of Relativity began to germinate in me, I was visited by all sorts of nervous conflicts... I used to go away for weeks in a state of confusion." But when he finished all the computations for the General Theory he was very confident. He was no longer assailed by self-doubts. He was very happy and wrote to his son Hans Albert. "I have just completed the most splendid work of my life..."

His original equations predicted that the universe is not static but is expanding. That was a bit too much even for him to digest. So he introduced a term, called the 'cosmological constant', so that the solution of those equations would predict only a steady state universe. He said so in the last lines of his papers. But when Edwin Hubble demonstrated unequivocally that the universe is constantly expanding Einstein realised his mistake. George Gamow to whom he had talked about this reported, "Much later, when I was discussing cosmological problems with Einstein, he remarked that the introduction of the cosmological term was the biggest blunder of his life".

Even after the Nobel Prize was conferred on him he continued to come up with earth-shaking discoveries.

Around the time he was being honoured, an unknown Indian physicist, Satyendra Nath Bose, sent him a paper for his comments and also with a request to help him get it translated in German. Einstein not only responded positively to both the requests but he also helped him get it published. He went further and extended the concepts put forward by Bose to predict a new state of matter that occurs at very very low temperatures. That state is now known as Bose-Einstein condensate. Its existence was finally demonstrated experimentally in 2002.

By the time the Nobel Prize was conferred on him substantial experimental proof of his theory of relativity was not available. But since then a number of phenomena that are the logical outcome of his theories have been observed. One such is the black hole. Since the gravitational pull of a black hole is so intense that even light cannot escape it, it is not easy to 'see' it. Yet, deploying some highly imaginative means it has been observed and even photographed.

Outstanding as these contributions are the one that would give pleasure even to a layman is the one in which he answered the question, 'Why is the sky blue?' What we term as the blue sky was according to him 'critical opalescence'. He attributed it to the cumulative effect of the scattering of light by individual molecules in the atmosphere.

1905 was certainly the Miracle Year. But other years over a span of almost 30 years were not far behind.

4
Back To The Future

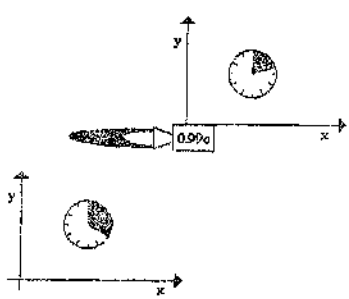
Familiarity, it is said, breeds contempt. That may be because familiarity does not necessarily mean full understanding or comprehension. That is certainly true about time. Time is one entity that everyone would aver he or she knows and knows well. Yet, the simple and preliminary question, 'What is time?' would leave one baffled.

As one attempts to come to grips with time, one encounters a number of incongruities. Time is one of the three fundamental entities that are measured. Yet, unlike the other two, length and mass, time is not tangible. It cannot be seen or handled. It has no size or shape or colour. It has no volume, nor mass. Still, man not only measures it but has also gone to great lengths to improve accuracy as well as precision of that measurement.

Time assumes a mystic, surreal character when one realizes that it has no beginning, nor end. It is eternal. It flows only in one direction, from the past to the future, though mathematics tells us that there is no earthly reason why it cannot go in the reverse direction.

As if these absurdities were not enough, Einstein queered the pitch with his theories of relativity. He promulgated that time is the fourth dimension, on par with the three dimensions of space. One can move freely in both directions along the three spatial dimensions. Does Einstein's statement that time is equal in status with those three imply that one can move in both directions along time axis as well? Science Fiction writers like H. G. Wells certainly think so. They have been entertaining us with all kinds of engaging tales of time travel.

But Einstein said something even more profound about time. He rocked the very foundation of our understanding, however feeble, of time, when he stated that it is not absolute. It is relative and depends on the frame of reference of the observer. The perception of time of someone who is stationary is different from that of one who is moving. The speed of movement thus would affect time itself. It would 'move slowly' or expand; the greater the speed the greater the magnitude of this dilation. These revolutionary concepts have given rise to all sorts of paradoxical situations. Einstein was acutely aware of these as he himself described one. He did not intend to cast doubts about his own theories but rather point out inadequacies of the other revolutionary



Time dilation

theory of those times, the quantum theory, which he did not totally approve.

Before one thinks of those enigmatic situations, however, one would like to know if Einstein's precepts about relativity of time are valid. If Einstein is correct then my watch should show one time when I am sitting in my chair and another if I am up and running. That does not happen. At least we do not notice any such difference, not even when we are travelling at the speed of Rajdhani Express or a jet plane. To be fair to Einstein, his theories do not predict that. He talks about time dilation when the speeds are very high, a significant fraction of that of light. One would naturally be prompted to query even that. Does time really dilate even at those speeds? That is what many scientists desired to find out. They, therefore, conducted some very imaginative experiments.

But before one talks about those experiments let us be clear about what exactly did Einstein say. He told us that contrary to earlier belief, fashioned by Newton, time is not absolute. It is relative. If the clock employed to compute time is standing still then the assessed time would be different than if it were to be measured with a clock that is in motion. Suppose there is an astronaut aboard a spacecraft travelling at very high speed. He has a clock to keep tab of the time intervals. Suppose also that we on the ground are able to see that clock. Now if we were to assess a particular interval of time with the help of that clock then it would not be the same as the one judged by that astronaut even though he too had been referring to the very same clock. Time thus would be relative dependent on the relative motion between the clock and the one using that instrument to measure that interval. Very high speeds affect time resulting in either expansion of time or contraction. That is what Einstein meant when he said that time is relative.

To test that hypothesis two physicists J. C. Hafele and Richard Keating conducted an ingenious experiment in 1971. They got hold of four extremely sensitive atomic clocks based on the vibrations of the caesium atom. They synchronised them with the chronometer that constituted the standard for time in the United States. The chronometer was placed in the US Naval observatory. That done, one of them boarded a jet plane with two of the four clocks. The plane was going on a round-the-world trip travelling in the easterly direction. The other carried the remaining two clocks and commenced a similar global journey but in the opposite, that is, the westerly direction. They returned home after three days having completed their trip around the world.

Time in all the four clocks was now compared with the one that the chronometer had maintained. If one thought that that would be unnecessary because they would all be the same one would be in for a rude shock. Jules Verne has narrated that delightful tale of Philius Fogg, who went around the world in eighty days. He had made that journey going from west to east. When he landed home all the clocks told him that he had missed his boat, oops sorry, his bet by a mere five minutes. However, Passepartou, his man Friday, discovered, in the nick of time, that they had, in fact, completed that journey one day earlier than scheduled. On reflection, Fogg realised that choosing to go in the direction he had, had allowed him to gain a day. That was fiction though the science behind that story was immaculate. But as they say truth is stranger than fiction. This is what the physicist duo discovered. The clocks on board the plane that had gone globetrotting in the easterly direction had lost 59 billionth of a second while his mate who had gone in the opposite direction found his clocks to have gained 273 billionths of a second.

According to Newton time is absolute. If so, all the clocks should show the same time, locked in step, as they were when the journeys had commenced. But that was not so because the clocks were not static but were moving either in the same direction as that of the spinning Earth or in the opposite direction. Consequently, their speeds were different. One always finds that swimming with the current allows one to go away faster. In contrast, one, swimming against the current, has to strive much harder and takes longer to cover the same distance. Though their physical efforts are identical their effective speeds are widely different. This is precisely what happened to the clocks on those two planes. It also indicated that speed of movement does influence time as Einstein had predicted. Further confirmation became available when the magnitude of that influence was computed in accordance with the doctrine of Einstein's theory of relativity. The time in the clocks going in the eastward direction should have fallen behind the chronometer by 40 billionths of a second. The other one should have gone ahead by 275 billionths of a second. Both the figures compared favourably with those actually observed providing the conclusive evidence needed to establish the veracity of the theory.

But even such a dramatic proof of the accuracy of Einstein's assertions did not satisfy some critics. They argued that the speeds of the jet planes, phenomenal as they are, are inconsequential compared to that of the spinning Earth. So to attribute the observed difference to difference in speeds may not be correct. On the other hand, these planes fly at dizzy heights, which might be responsible for the crazy behaviour of the clocks.

That may appear to be a rather facetious argument. Those were not any ordinary clocks. They were the most sensitive atomic clocks. They are not affected by any external factors like temperature or atmospheric pressure. So the low temperature or low atmospheric pressure at what were termed dizzy heights could not force them to go astray. Moreover, both the planes were flying at the same altitude. Thus all the clocks spent three days at the same height. They should have all lost time. Or gained. And to the same extent. That did not happen. If two of them swerved one way, the other two erred on the opposite side. Why should they be affected to differing extents? In opposing directions? That kind of reasoning flies in the face of logic.

Still, the sceptics were not totally off the mark in suggesting that height above the mean sea level would bring about a change in time. That is again because of another tenet of the relativity theory. Einstein had proposed that just as speed of motion influences time so does the force of gravitation. The stronger the gravitational pull, the slower is the march of time. On the other hand, the weaker this force, the faster is the flow of time.

Now we know since the time of Newton that the magnitude of that force is directly proportional to the product of the masses of two objects and inversely proportional to the square of the distance between them. If the distance increases two fold, the magnitude of the force is reduced to one fourth of its former value. As the distance triples, the magnitude of the force becomes one ninth of the initial level. When an object is on the surface of the Earth the gravitational pull would be at its maximum. However, as that object ascends in the sky its distance from the centre of the Earth increases. The gravitational attraction then would correspondingly become more feeble. That should result in time moving faster. If a clock is placed on top of the Mount Everest it would run faster compared to the one at sea level.

Logical though this contention sounds, there is the need for proof. To silence the doubting Thomases another inspired experiment was carried out in the seventies.

An aircraft belonging to the American navy was made to fly at an altitude of 10,000 metres, which is approximately the height of Mount Everest. It kept circling in a radius of 35 kilometres. The command centre on the ground sent out a laser beam every three minutes. On receipt of that the plane responded by sending an identical beam to the ground control. This interval of three minutes was counted both by the command centre and the plane. The aircraft kept continuously flying at that altitude for fifteen hours. It was seen that the clock in the plane kept creeping ahead by three billionth of a second every hour. By the time the plane landed back it had 'aged' by as much as fifty billionths of a second compared to its counterpart on the ground.

The experiment was repeated each month between September 1975 and January 1976 with unambiguous and identical results. Some critics did argue that this did not reflect the impact of gravity but that of the speed of the plane. That does not hold water since the plane went round along a circular path. It if flew with the spinning Earth for half of that orbital path it went in the opposite direction for the rest of the cycle. So the effect of speed was cancelled out.

Demonstrations of these proofs once again gave currency to the thought of time travel. One is able to freely go on a journey in any one of the three dimensions of space. One can move backwards or forwards. Moving sideways along the second dimension one can go the left or to the right. Likewise one can ascend to higher levels or descend the depths as one pleases. If time is the fourth dimension, equal in status with all these three, then it should be possible to travel to the past or leapfrog into a distant future as per one's wishes. That is what time travel means to the common people. True, one requires some vehicle to move along in space, either the legs given by nature or some other like the bullock cart or bicycle or a jet plane. No such vehicle to proceed on a journey in the dimension of time is as yet available. But should it be produced sometime it should be possible to undertake such a journey. That is what everyone believes.

That is true up to a point. Even so, there are a number of difficulties in accomplishing that. Several paradoxes crop up. So even though it appears possible in principle, in practice it would tamper with our familiar universe to such an extent that we would be totally bamboozled.

Pretty often we say 'now' or 'at this moment'. We know what we are saying when we utter those words; nor is our listener left in any doubt about their meaning. But when we start analysing that statement from the perspective of relativity the implications do not remain that cut-and-dried. The terms 'simultaneously' or 'at the same time' do not normally cause any confusion in our minds. When two separate events take place at two different locations in space concurrently we call them simultaneous. That is our familiar world though. In the relativistic parlance, it is not so simple. We would be correct in referring them to be simultaneous only if both those locations where the events have occurred are static. If, however, they were in a state of motion and moving with a significant speed at that, then the statement would have to be qualified.

Suppose, two spacecrafts are hurtling through space alongside each other. Both of them are orbiting at the same speed. To us on the ground they would appear to be maintaining a cracking pace. To each other, though, they would appear to be standing still. We experience that while travelling in a train at speed. If another train moving equally fast on the adjoining track comes into our view, we feel that it is not in motion at all.

Commanders of those two spacecrafts now conduct an experiment. One of them sends a signal to the other by flashing a light. The other acknowledges its receipt by transmitting a return signal in the same fashion. To those commanders the two signals would seem to have travelled in a straight line. To us looking at the whole episode from our position on the ground the situation would be radically different. From the moment the flash of light left the first spacecraft till it is received by its companion, it would take some finite time. Since the spacecrafts are moving along at a significant speed the receiving spaceship would have moved some distance. So the path of the signal would appear to be making an angle to the line joining the two vessels. Likewise the return signal too would move along a line making the same angle in the opposite direction. The total return path would thus form two sides of an equilateral triangle.

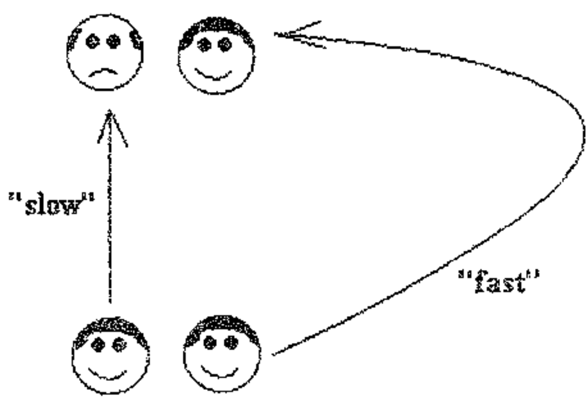
The beams of light travelling along a straight line as envisaged by the two commanders would have covered a total distance that is equal to twice that of the distance between the two crafts. The distance along two sides of a triangle nonetheless would be more than that. Let us say that by the reckoning of the commanders the total time taken by the beams to complete the return journey is 100 seconds. The time taken to cover the increased distance along two sides of an equilateral triangle would be different. It would depend on the speeds of those spaceships. If they are moving at a speed half that of light the time spent by the beams moving along two sides of the equilateral triangle would be fifteen percent more. In other words, the time needed for the light flashes to make the return trip as measured by us on the ground would be one hundred and fifteen seconds. Since the time computed by the two commanders for the same event is only hundred seconds we would feel that their clocks are moving slowly.

The events are the same. They have occurred at fixed times. But whether they would qualify to be called simultaneous or not would depend on the state of motion of the onlooker and also the relative states of the spectator and the spectacle.

This is by no means the only enigmatic situation. There are others, as those who understood all the intricacies and implications of Einstein's theories pointed out. One such is known as the Twin Paradox.

Gravitational pull slows down time. Einstein had found that out with one of the equations constituting the theory of relativity. The entity that has the maximum gravitational attraction in the universe is the black hole. The force of gravitation of a black hole is so great that even light cannot escape from it. Thus its name. Naturally such a severe pull would bring time to stand still even in its immediate vicinity. It gets frozen.

Now imagine that there are twin brothers. If they spend their entire life on this Earth then both of them would grow old together. Their age at any moment would be the same. Because, in their case, time would be moving at the same rate. But one of them gets it in his head to visit a black hole and go round it once. Actually, he would not be able to reach the black hole. For, if he really does, he would get permanently trapped inside. He would not be able to overcome its gravitational pull and would not be able to leave it at all. He can, however, approach it and get a bird's eye view from a safe distance. Even at that distance he would be subjected to a very high force of gravitational attraction. Naturally time in his case would be making very slow progress. That is why when he returns from that fascinating sojourn to give a wonderful account of his travels, he can boast of youthfulness. Compared to his twin brother who



Twin Paradox

had not felt venturesome and remained rooted to the Earth he would be far younger. If the ages of twins thus started differing by vast margins the whole familiar world would go crazy. The very foundation of our living process would get shaken. Jayant Narlikar, the astrophysicist and disciple of Fred Hoyle, has written a delightful science fiction short story based on this paradox. The hero of his tale makes a journey to the black hole and back and gets to marry the daughter of his classmate. While his friend had aged by twenty years, his own age had advanced barely by a year. He and his bride, therefore, lived happily ever after. That is fiction, nonetheless. In real life one would not encounter such happy ending after time travel!

It thus seems that there is one rule for travel in space and another for travel along time axis. This dichotomy seems to be Nature's way of running things. It is not Einstein's doing. He has merely depicted the universe in its true colours. He has nicely wrapped it up in the form of some elegant equations. Those have been subjected to stringent experimental tests. The equations have passed those tests with flying colours. If all those colours give one the blues poor Einstein cannot be held responsible. Those are the colours Nature has chosen to don. According to those very ways of Nature time travel seems to pose unsurmountable problems. It does not seem to be as free or facile as space travel. But it is not Einstein who has put up those obstacles. They are natural. If Nature itself has deemed time travel improbable, it cannot be helped.

The twin brothers' paradox has already demonstrated some of those hurdles, which confront a prospective time traveller. There are others. One of the underpinnings of Einstein's theory is that nothing can move faster than light.

The speed of light is the ultimate speed limit in the universe. Time is affected by the speed of motion; but time is not the only entity to be so affected. The speed of motion also impinges on length and mass. Any entity moving at the speed of light would contract to such an extent that its length would become infinitesimally small, almost zero. In contrast, its mass would become infinite. In short, the entity would assume the status of a singularity, which is what the universe was before coming into being in its present state. In practice, this would be highly improbable, well nigh impossible. That entity would not be able to survive such a catastrophic change in its character.

There are other complications. One of these has been described very eloquently in the form of a limerick. The limerick had become very famous at the time it was first published. It relates the story of the voyage that one girl undertook. It goes like this:

There once was one Miss Bright
Who travelled faster than light
She started one day
In the relativistic way
And returned home the previous night.

Such an utterly bizarre journey would cause sheer pandemonium. If one arrived at one's destination even before the commencement of that expedition it would lead to complete disorder. If the impact of any action or an event were to manifest itself even before the occurrence of that event or action, it would rock the very foundation of this universe. The causality principle, the one that clearly specifies the relationship between cause and effect would get thrown out the window.

That anarchic situation is very charmingly described in the story of one Somaji Gomaji. Somaji was disgusted with the life doled out to him by Nature. He was extremely unhappy with his lot. Thinking that the genetic legacy handed out to him was responsible for his deplorable state he decided to take matters in his own hand and do something about it. So he travelled back in time to the distant past when his grandfather was a mere toddler. He murdered him in his infancy. He thought he had worked out a very neat solution to his problem. But since his grandfather died in his childhood he did not grow to manhood and obviously did not marry. Naturally he could not sire any children including Somaji's father. Since the latter did not set foot in the world he could not give birth to Somaji. But if Somaji was not even born then how could he go back in time to kill his grandfather? And if the grandfather were not killed when he was very young what would prevent him from getting married eventually and produce children of his own? Why cannot one of them, in turn, give birth to Somaji? How could his lot undergo any change under those circumstances?

Time travel certainly holds a good deal of attraction to everyone. One would like to travel backwards in time and witness, say, the epic war of *Mahabharata* or enjoy the golden age of Chandragupta Maurya or march with Shivaji Maharaja's army. On the other hand, some may like to jump into the future, say to the year 2300 and journey to one of the planets aboard a jumbo spacecraft. Fascinating as time travel is, Nature seems to have put a lot of obstacles in the way and almost forbidden it. Until Einstein depicted these facets of time, the world was blissfully unaware of it.

5
The Inventor

Albert Einstein was a genius. There are no two opinions about it. His ideas and mathematical calculations forever changed our understanding of the universe. Our concept today of the way this universe is structured and the manner in which it conducts itself owes a great deal to his thoughts.

Even so, there are a few skeptics who wonder why we fuss so much about him. There are some diehard critics like Sam Sloan, who ask if Einstein was not a hoax, a fraud. There are not many who go to that extreme. Still, they do have their reservations. They think that his deliberations are very esoteric and concern matters celestial. They deal with the vast cosmos out there. They do precious little to lighten our daily tribulations or to ease our daily load of chores.

One harassed lady made bold, we are told, to confront the great man and ask him face to face,

" Is your work of any use to us at all?"

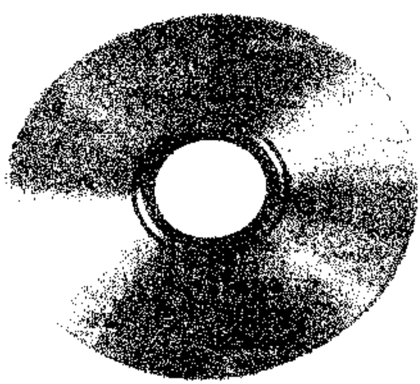
Einstein was not flustered by this frontal attack. He kept his cool while responding,

"You are right, m'aam. What I do has no relevance to your daily life. In a way I am quite a useless person."

That speaks volumes for the humility of the sage. Whether that self-effacing reply satisfied the old lady or not, we do not know. But was he on target when he made that statement? Was he really as useless as he proclaimed himself to be?

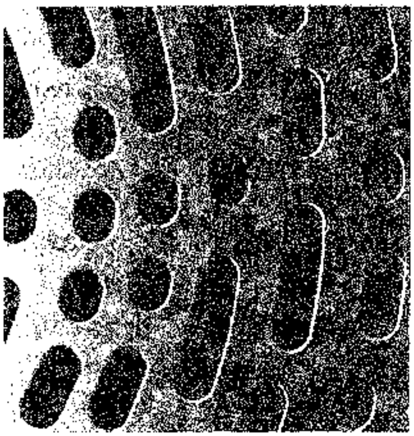
Looking around today one would tend to disagree with him. A large number of gadgets and appliances that we take for granted and deploy in our daily routine owe their existence to the new directions he gave. He may not be the inventor of those devices but they would not have seen the light of day had it not been for the basic principles that he propounded and paved the way for their manufacture.

Take, for example, the ubiquitous compact disc (CD). Till the other day, we used to store our information or music or pictures on a cassette tape. Video recording of important events in our life like the birth of a child or its first day in school, later still her graduation or wedding was kept on a tape. Today the tape has given way to compact disc. Not only much larger amounts of information can be stored on the disc but it also resists corruption. So it is much more secure and the quality of retention is also very good. Computers also prefer compact discs or their advanced siblings the digital video discs, for storage of data.



CD

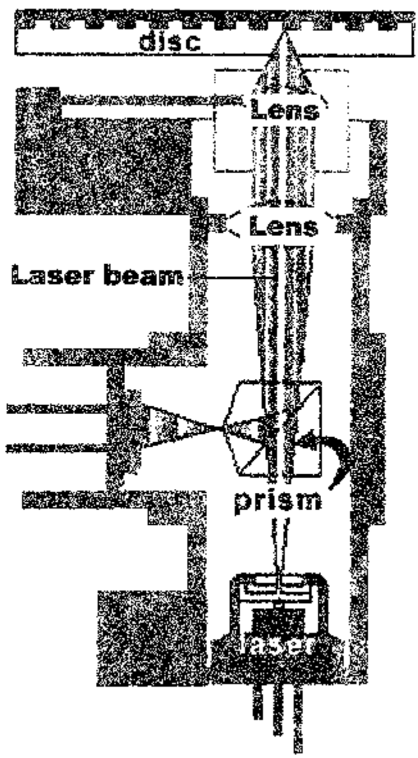
The driving force behind all these discs is the laser, which emanated from one of the principles propounded by Einstein. A CD, which is barely 12 cm in diameter, can store up to 74 minutes of music or more than 780 million bytes of information. A DVD can hold even more. A CD is a fairly simple piece of plastic, about 1.2 mm thick. A long continuous spiral groove or track is etched on this.



CD pits

When music is recorded on the CD it is actually the sound of music that is embedded in the plastic material. When we hear sound, we are actually sensing air pressure changes. Microphones have a small membrane that responds to variations in pressure by vibrating. This motion generates a small electric current. The electric potential created by the microphone is measured about 44,000 times per second on a numerical scale ranging from 0 to 65,535; these numbers are stored digitally on tape as sequences of zeros and ones. The zeros and ones, along with timing information, are printed as tiny depressions on a CD. Each of these pits is 0.5 micrometres wide, a minimum of 0.83 micrometres long and 125 nanometres deep. (A nanometre is a billionth of a metre.)

A small but extremely well focussed laser beam in a CD player reads these depressions. As the CD rotates, the information is translated into a sequence of signals. These signals are again interpreted as strings of zeros and ones, re-creating the original digital signal. The decoded numbers are translated back into voltages, and the resulting electric signals are sent to a speaker. The speaker's membrane moves the same way as the microphone membrane.

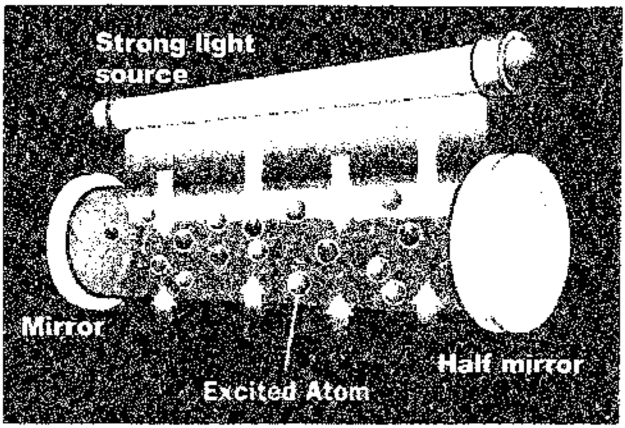


CD player

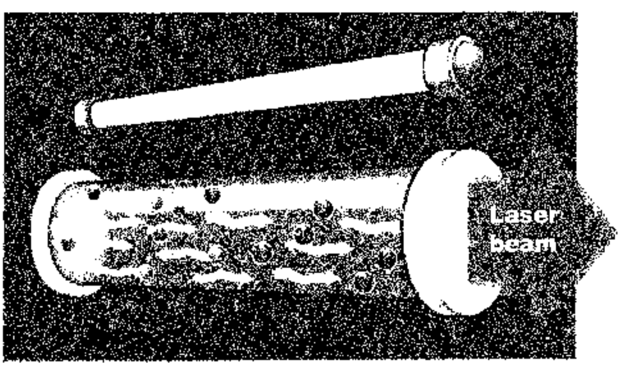
The fundamental job of the CD player is to focus the laser beam on the track of bumps and pits. The laser beam is able to pass through the plastic layer but gets reflected when it collides with the aluminium layer. The depressions reflect the light to a different extent than the flat aluminium surface, which is called the land. The reflected beam then falls on an opto-electronic device. The changes in reflected light are detected and measured by that device, which is sensitive to light and is able to convert the light signal into an electric signal. That helps the rest of the electronic circuits to interpret those changes in reflectivity. Since the magnitude of the change depends on the information stored within the opto-electronic device is able to read the information and then transform that to a mode that we can easily understand. So if the stored information is music the electric signals get converted to sound signal and we are able to hear the melody.

Einstein had first enunciated the principle of laser, which is an acronym for Light Amplification by Stimulated Emission of Radiation. Whenever an atom acquires some energy it gets excited. Such excited atoms are, however, unstable and like to return to the stable ground state by releasing the excess energy. This is achieved by emitting a photon, which is a quantum of light. Einstein demonstrated mathematically that this normal process could be modified, by creating appropriate conditions, to yield intense and coherent beams of light. In other words, by stimulation they can be coaxed to generate highly powerful beams of light.

Laser light is very different from normal light. For one it is monochromatic; that is, of a single colour. Normal light is made of a large number of colours. In scientific parlance it is said to consist of many wavelengths. But laser light is made of only one specific wavelength. Secondly, it is very coherent or organised. The difference between a laser and normal light is the same as that between a marching army column and a motley crowd. Laser is orderly, whereas normal light is chaotic.



Laser 1



Laser 2

When Einstein enunciated the principle of lasers it evoked only academic curiosity. No one thought at that moment that his theory could be applied to come up with such a practical device that has so many benefits. Lasers are used today in scanners that read the bar coded price tag on many goods. They are used for transmission of data across vast distances. They are used to weld together tough materials. And they are also used to carry out bloodless surgery. A powerful laser can cut through layers of tissue more easily than a sharp knife. Because it can seal open blood vessels, the surgery can be carried out without loss of blood. Today, it is the first choice for several operations on the delicate organ of the eye, especially for removal of cataracts and for correcting short-sightedness.

Another very useful device that has come into being as a result of Einstein's theories is the global positioning system (GPS). One finds GPS in advanced automobiles as a navigational aid to the driver. What the driver does is to type into the system the location of his destination. The GPS then reads the map and finds the best route to reach there. It then directs the driver by showing the distances to travel along a particular road as also the turns he should take along the way. Some systems also 'talk' to the driver when giving instructions.

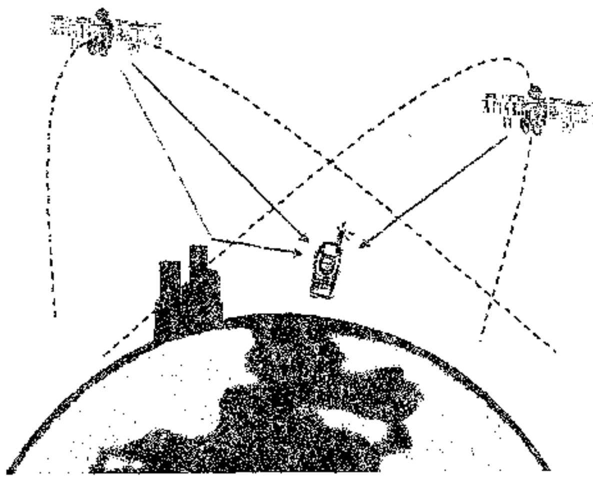
GPS is a worldwide radio-navigation system formed from a constellation of 24 satellites with their accompanying ground stations. GPS uses these "man-made stars" as reference points to calculate positions accurate to a matter of metres. In fact, with advanced forms of GPS one can measure distances accurate to less than a centimetre!

In a sense it's like giving every square metre on the planet a unique address. Miniaturisation technology enables reducing the size of GPS receivers. Not more than a handful of integrated circuits are required for the purpose. That cuts down costs considerably and makes GPS very affordable. These days GPS is finding its way into cars, boats, planes, construction equipment, movie making gear, farm machinery, and even laptop computers. Even hand held GPS device is now on the market so that a pedestrian can also find his way in a new town on his own. Soon GPS will become almost as basic as the telephone.

The principle underlying GPS is quite simple. We always use a reference point to determine the location of any building or person. Thus, a house would be located 100 metres to the west of the post office. GPS uses satellites in space as reference points for locations here on earth. It does so by measuring our distances from three or four satellites very, very accurately. In the language that scientists use, this method is called triangulation.

GPS starts with a satellite and measures distance of a particular location from it. Let us say that it is 10,000 kilometres. Immediately, that location gets fixes to a circle of a radius of 10,000 kilometres from that reference point. Now the distance of the same location from another satellite is measured. Suppose that is 12,000 kilometres. So the location is on the circumference of another circle. These two circles would cross each other along an arc. The location would be somewhere on that arc. To know exactly where it is a third satellite is used as a reference point to obtain yet another circle. The arc would intersect that circle at just one or two points, which would pinpoint the exact coordinates of our location.

Thus by using three satellites as reference points the



GPS System

position of our location can be narrowed down to the precise point on the wide expanse of earth. To ensure that this situation is reached it is essential that our measurement of the distances is quite accurate. That may appear difficult since the satellites are not stationary objects but are moving in space. For that matter the Earth is also not stationary. It is also constantly on the move. Still the distances can be measured precisely by determining the time it takes for a signal that is sent to the satellite to return to the ground station. Einstein's theories about the curvature of space and speed of light are of great help in determining this time very accurately. Einstein is thus indirectly responsible for the development of this highly useful technology.

GPS technology had very limited objectives when it was designed. Today it has transcended those goals. It is proving to be a very reliable ally to people in all walks of life. Not only scientists but also sportsmen, farmers, soldiers, pilots,

GPS Receiver

surveyors, hikers, delivery drivers, sailors, postmen, fire-fighters and many others depend on it for their regular work. It makes their task much lighter, safer and more productive.

Einstein may have ushered in GPS indirectly through his insight into the structure of this universe. On the other hand, the advent of nuclear technology can be directly traced to ideas propounded by him. His equation $E = mc^2$, where E represents energy, m, mass and c, the velocity of light, has now become world famous. That equation demonstrated the interconvertibility of mass and energy. Taking a cue from that, other scientists found a way of splitting atoms and releasing the enormous amount of energy stored within. Though the man in the street came to know of the existence of nuclear energy in an extremely tragic and traumatic fashion over the skies of Hiroshima and Nagasaki, it has a vast potential of being a very reliable help to mankind.

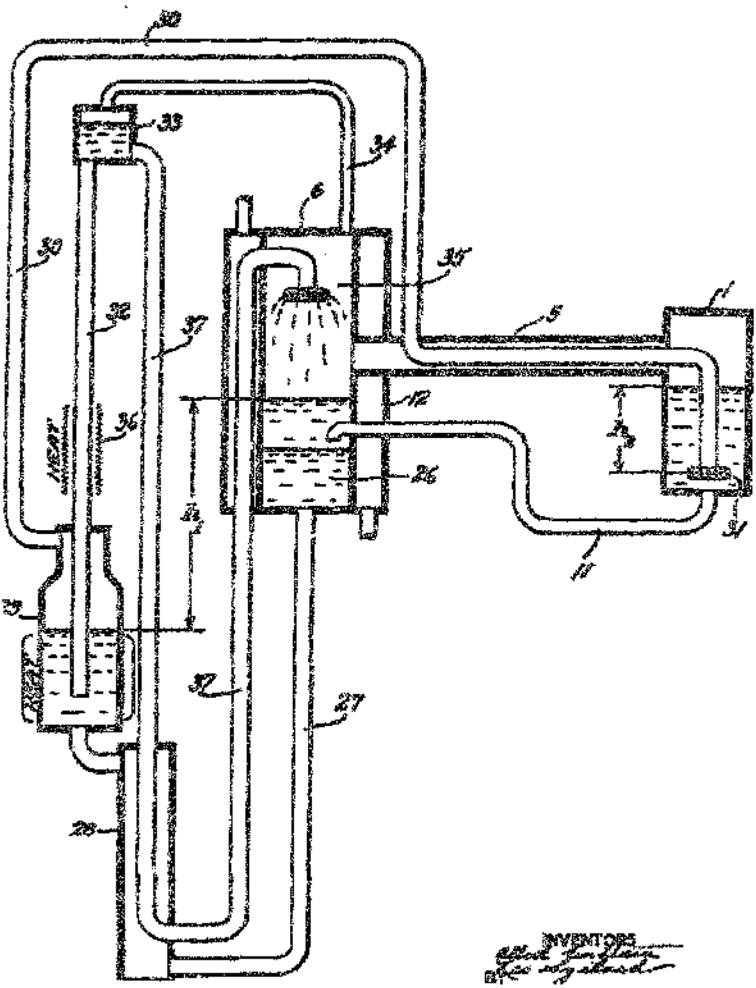
Today, nuclear energy is used for lighting our houses, for diagnosis of diseases, for curing cancers, and sterilising surgical bandages as well as disposable syringes.

Though all these and many more technologies of everyday use originated from theoretical propositions put forward by Einstein he cannot be considered to be inventor of the consequent contraptions that make our lives more cheerful. There is one implement, however, which was invented by Einstein and for which he even holds a patent. Unknown to many, Einstein, with the help of lifelong friend Leo Szilard, had invented a refrigerator that is considered superior to those, which have found their way into our homes.

Szilard's collaboration with Einstein apparently began in the winter of 1925-1926 with a newspaper article. One day Einstein read about the death of an entire family, parents and several children, who had been killed in their beds by the poisonous gases leaking from the pump of their refrigerator. At the time, such accidents were a growing hazard. Mechanical home refrigerators were starting to replace traditional iceboxes. However, there was no safe refrigerant. The three common refrigerants were methyl chloride, ammonia, and sulphur dioxide. All were toxic, and the amount in a refrigerator was enough to kill its owner. Einstein was distressed by the tragedy. "There must be a better way," he said to Szilard. This was the beginning of a fruitful collaboration that lasted for the next seven years. In all, the scientist duo filed more than 45 patent applications in at least six different countries. At that time most household refrigerators employed mechanical compressors. This is true even today. The gas used for refrigeration is compressed by motors. When the compressed refrigerant is released through a fine orifice it cools. Such cooled gas is then circulated throughout the refrigerator. Absorption type refrigerators, on the other hand, use heat from a natural gas to drive absorption and release from a chemical solution. That is why Szilard and Einstein thought it to be the safest among all available options.

The Einstein-Szilard refrigerator is basically an absorption-type refrigerator that uses ammonia, water and butane to create a chemical phenomenon that allows one to run the whole thing at a constant pressure. So it doesn't need moving parts like a pump or a compressor. It provides cooling with only heat as an input. Literally, as one end is heated, the other end gets cold. Because it has no moving parts, the possibility of break down gets minimised. It can be expected to last a hundred years without any kind of maintenance. Perhaps the most marketable quality of "Einstein's refrigerator" is that it does not require electricity to operate. Since all that is needed is a heat source, models could be designed that use a small gas burner or even solar energy. Thus the refrigerator could be useful in remote or underdeveloped areas and for camping and recreational vehicle applications.

The pair of these illustrious scientists did not stop with one design, however. They produced many ideas, all without moving parts, and in early 1926, Szilard began filing a series of patent applications on their inventions. The most promising patents for refrigerators granted to them were quickly bought by the Swedish company AB Electrolux to protect its refrigeration technology from competition. A few demonstration units were constructed from the other patents but regular production was not started. Thereafter, Szilard quickly negotiated a contract with the Bamag-Meguin



Einstein's refrigerator design

Company, and by late 1926 development of prototypes began under Szilard's supervision in the laboratories of Berlin's Institute of Technology.

Unfortunately, the agreement with Bamag-Meguin lasted less than a year because the company developed financial problems. Within months, however, Szilard and Einstein reached agreements with two other companies, one German, one Swedish. In Stockholm, Sweden, the Electrolux Company still keeps files on two patents purchased from Szilard and Einstein. On December 2, 1927, the scientists sold a patent application on an absorption refrigerator to Platen-Munters Refrigerating System, a division of Electrolux, for 3,150 Reichsmark, or 750 US dollars.

The most important, and most successful, invention of the collaboration between these two innovative geniuses was, however, quite a different one. It is known today as the Einstein-Szilard electromagnetic pump. It was a fully functional pump without mechanical moving parts of any kind. Instead, a travelling electromagnetic field was used to move a liquid metal. The liquid metal, in turn, could be used as a piston to compress a refrigerant. The Einstein-Szilard pump, later found a higher use in sophisticated nuclear reactors. It was a very ingenious application of the principles of thermodynamics. Advanced versions of this pump are deployed today in cooling systems of breeder reactors.

Despite having proved its utility none of the refrigerators reached the market. This was no doubt partly due to lack of finances and active support from Industry. But the main reason lay in another development. A new type of refrigerant was first demonstrated in 1930 in the U.S.A. That refrigerant was Freon. Because it was non-toxic, it eliminated the danger from leaks. In just a few years, compressor refrigerators using

Freon became the standard for almost all household equipments. Only decades later, of course, would it be realized that such chlorofluorocarbons like Freon endanger the protective ozone layer of the entire planet. Search is, therefore, on for eco-friendly refrigerators.

So, after all, perhaps Einstein and Szilard had a better, and what would be considered today a 'green' idea.

6
The Liberal Rebel

Albert Einstein was not a politician, at least not in the conventional sense. He was not an official member of any political party; nor did he covet a political office in any of the countries that he resided in during his lifetime. Not that there were no opportunities. When the UN mandate established the fledgling nation of Israel, the then Prime Minister of that country, David Ben Gurion, invited him in 1952 to become its President. He politely declined the offer.

However, in today's world of *real politik* no one is allowed to have the luxury of remaining apolitical or neutral. If one does not subscribe to a particular political ideology, he is considered to be against it. That is why Einstein was branded a communist and J. Edgar Hoover, the Director of Federal Bureau of Investigation (FBI) in the US kept him under strict surveillance for a long time. The FBI compiled a very thick file on him and even interrogated him at one time.

It is true that the US of that time had become paranoid, with Senator McCarthy finding a communist in everyone who disagreed with him. But the reason for Einstein being regarded as a communist spy can be found in his strong humanitarian beliefs. Instinctively Einstein abhorred authoritarianism of any sort. He thought that regimentation inhibited freethinking, which is necessary for real learning. That was his problem even in the school. He despised the rigid hierarchical atmosphere in German schools of those times and rebelled against it. He did not mind even being asked to leave the school. Even at that relatively young age of 16 he renounced his German citizenship and became a Swiss citizen. The more liberal atmosphere of the Swiss schools suited him and he flourished there. Even so, he chose to address the principal of his school simply as 'Herr Weber' instead of the more formal manner everybody else adopted.

His initial alienation from the inflexible school teaching turned him towards religion. He was born a Jew but his parents were not deeply religious. They did not enforce any religious regimen or dogma on him. Yet, what he himself has described as his "positively fanatic indulgence in free thinking" nudged him in the direction of religion. For a while, he remained under the spell of the Bible. That did not last long. Soon, as he revealed later, "through reading popular science books I came to doubt the stories of the Bible. I found new enchantments. First, at age twelve, I read a little book on Euclidean plane geometry." He called it "holy," a veritable "Wunder." Then, still as a boy, he became enchanted by the stimulating thoughts underpinning the huge external, extra-personal world of science, which presented itself to him "like a great, eternal riddle." He surmised that in order to gain "inner freedom and security" he would have to devote his life to pursuit of science.

Steven Yates has tried to suggest that his obsession with freedom and his egalitarianism, the philosophical view that everyone is equal and free, stems from peculiar features of his brain. After his death his brain was removed at autopsy.

Sandra Witelson of the McMaster University in Canada studied its anatomical make-up.

The area of the human brain thought to be the seat of mathematical, visual, and spatial reasoning is known as the inferior parietal region. It is located around the temples in the part of the brain known as the cerebrum. What Witelson and her team found was that Einstein's inferior parietal lobes were 15 percent wider than those of a control group of 91 "normal" brains. In Einstein's brain, a cleft known as the Sylvian fissure was much different from its usual structure found in the brain of other normal healthy individuals. Apparently, the change occurred when Einstein was in his infancy. It did not permit Einstein's brain to develop what is called a sulcus, a groove that normally runs through that part of the brain. The neuroscientists theorized that the absence of this groove may have allowed far more neurons – brain cells that facilitate thinking and communicating – to develop and exchange information. Yates thinks that this peculiarity of his brain structure also instilled in him the modality of thinking that culminated in his utter distaste for war, cruelty and inhuman behaviour.

In an essay entitled "The World As I See It", which Einstein wrote in the 1930s, he has expressed his basic philosophy. He says: "I have never looked upon ease and happiness as ends in themselves – this critical basis I call the ideal of a pigsty. The ideals that have lighted my way, and time after time have given me new courage to face life cheerfully, have been Kindness, Beauty, and Truth. Without the sense of kinship with men of like mind, without the occupation with the objective world, the eternally unattainable in the field of art and scientific endeavours, life would have seemed empty to me. The trite objects of human efforts – possessions, outward success, luxury – have always seemed to me contemptible."

He goes on to state, "My political ideal is democracy. Let every man be respected as an individual and no man idolized. It is an irony of fate that I myself have been the recipient of excessive admiration and reverence from my fellow-beings, through no fault, and no merit, of my own. The cause of this may well be the desire, unattainable for many, to understand the few ideas to which I have with my feeble powers attained through ceaseless struggle. I am quite aware that for any organization to reach its goals, one man must do the thinking and directing and generally bear the responsibility. But the led must not be coerced; they must be able to choose their leader. In my opinion, an autocratic system of coercion soon degenerates; force attracts men of low morality... The really valuable thing in the pageant of human life seems to me not the political state, but the creative, sentient individual, the personality; it alone creates the noble and the sublime, while the herd as such remains dull in thought and dull in feeling.

"This topic brings me to that worst outcrop of herd life, the military system, which I abhor... This plague-spot of civilization ought to be abolished with all possible speed. Heroism on command, senseless violence, and all the loathsome nonsense that goes by the name of patriotism — how passionately I hate them!"

Throughout his scientific pursuits Einstein was driven by the desire to obtain a universal perspective. He was not satisfied with laws that applied to a restrictive physical state or condition. He did not want to be constrained by any boundary conditions. He wanted to look at a picture, which was valid and the same no matter which point in the universe one viewed it from. The General Theory of Relativity, which is rightfully considered to be his most profound contribution, was the inevitable culmination of this pursuit.

That passion to obtain 'a comprehensive *Weltanschauung*' one yielding a total conception that, as he put it, would include every empirical fact (*Gesamtheit der Erfahrungstatsachen*) – not only of physical science, but also of life – moulded his social and political ideas. Gerald Holton came to the same conclusion when he said, "As in his science, Einstein also lived under the compulsion to unify – in his politics, in his social ideals, even in his everyday behaviour. He abhorred all nationalisms, and called himself, even while in Berlin during World War I, a European."

Though intensely passionate about freedom and equality Einstein was not very vocal publicly in his early career. But once his exploits during the Miracle Year became widely known and his fame grew he started making his views known openly and even putting them into some positive action.

The outbreak of the First World War stirred Einstein into action. By then his reputation as a thinker par excellence had already taken root. He could no longer withhold himself from airing his views openly. Things came to a head when ninety-three leading German intellectuals, including physicists such as Planck, signed a manifesto defending Germany's war conduct. Einstein and three others signed an antiwar counter-manifesto. He helped to form a non-partisan coalition that fought for a just peace and for a supranational organization to prevent future wars. He was firm in his belief that war ruins human lives in more ways than one. Since he was a Swiss citizen it was not incumbent on him to serve the army. He could have continued to engross himself in his world of theoretical physics. But, he refused to do so and publicly urged young Germans to defy the official dictum.

The German authorities did not take kindly to that stand. That was understandable; but even the public thought him to be a traitor. Other intellectuals also started distancing themselves from him. His popularity plummeted. Even an anti-Einstein society was founded. Members of that body tried to besmirch his scientific reputation which had given him world standing. They published a book entitled. "100 Authors against Einstein." He ridiculed the pitiable attempt by saying that, "If I am incorrect, one author would have been enough."

People had not understood that he was not against the German nation only its aggressive military machine. That became clear when Germany lost the war and total chaos prevailed. A number of self-styled workers and soldiers councils proliferated. One of Einstein's lectures at the University of Berlin was "cancelled due to revolution." On November 16 Einstein was one of the original signers of a manifesto announcing the creation of a progressive middle-class party, the German Democratic Party. After a democratically elected assembly met in Weimar, Einstein formally accepted German citizenship as a gesture of support for the infant republic.

With his scientific fame firmly established, Einstein could act as unofficial spokesman for the Weimar Republic, and he protested the continued hostility of Germany's former enemies. In 1921 he refused to attend the third Solvay Congress in Belgium, since all other German scientists were excluded from it. In 1922 he joined a newly created

Committee on Intellectual Cooperation set up under the League of Nations. The next year he resigned, distressed by the League's impotence when confronted with France's occupation of the German Ruhr. But he soon returned to the committee. As a leading member of the German League for Human Rights, he worked hard for better relations with France. He also made numerous gestures against militarism.

Einstein attracted attention to a number of causes, such as the release of political prisoners and the defence of democracy against the spread of fascism. He spoke in public, made statements to the press, signed petitions. In 1924 he defended the radical Bauhaus School of Architecture; in 1927 he signed a protest against Italian fascism; in 1929 he appealed for the commutation of death sentences given to Arab rioters in British Palestine.

Anti-Semitism was openly pursued by the powerful political right and the emerging Nazi party since 1919. Nazi physicists and their followers violently denounced Einstein's theory of relativity as "Jewish-Communist physics." At times his friends feared for his safety. Such anti-Semitism was one reason why Einstein, although he believed in world government rather than nationalism, gave public support to Zionism. "In so far as a particular community is attacked as such," he said, "it is bound to defend itself as such, so that its individual members may be able to maintain their material and spiritual interests... In present circumstances the rebuilding of Palestine is the only object that has a sufficiently strong appeal to stimulate the Jews to effective corporate action." But he objected to a law that required him to join the official Jewish religious community in Berlin. He said, "Much as I feel myself a Jew, I feel far removed from traditional religious forms."

His problems got compounded when Hitler came to power. Although he was not a practicing Jew, he had publicly supported the Jewish movement of Zionism. That angered the right wing anti-Semitic element in the country. Hitler would have found that a handy tool to punish Einstein. Sensing that, he permanently moved to the United States in 1933.

Once at the Institute of Advanced Studies at Princeton, he continued his quest for the grand unification theory, which aims at showing that all the four fundamental forces that hold the universe together and make it run smoothly are but different manifestations of a single force. Still, he found time to be in touch with several intellectuals from all parts of the world and promote pacifist social activities.

He kept company with such luminaries as Bertrand Russell, Romain Rolland, Thomas Mann, Stefan Zwieg and signed petitions and appeals along with them. He gave public lectures. He used the medium of radio, which had become quite popular by then.

During a stay in England in September 1933, Einstein met with Winston Churchill, Lloyd George, and prominent British scientists and intellectuals. He tried to warn them of the Nazi danger. But England was in a mood to appease Hitler at that time and did not pay much heed to his prescient warning.

Scientists in the 1930s, using machines that could break apart the nuclear cores of atoms, confirmed Einstein's formula $E=mc^2$. The release of energy in a nuclear transformation was so great that it could cause a detectable change in the mass of the nucleus. But the study of nuclei – in those years the fastest growing area of physics – had scant effect on Einstein. Nuclear physicists were gathering into ever-larger teams of scientists and technicians, heavily funded by governments and foundations, engaged in experiments using massive devices. Such work was alien to Einstein's habit of abstract thought, done alone or with a mathematical assistant. In return, experimental nuclear physicists in the 1930s had little need for Einstein's theories.

In August 1939 nuclear physicists came to Einstein, not for scientific but for political help. The fission of the uranium nucleus had recently been discovered. A long-time friend, Leo Szilard, and other physicists, realized that uranium might be used for enormously devastating bombs. They had reason to fear that Nazi Germany might construct such weapons. Einstein, reacting to the danger from Hitler's aggression, had already abandoned his strict pacifism. He now signed a letter that was delivered to the American president, Franklin D. Roosevelt, warning him to take action. This letter, and a second Einstein-Szilard letter of March 1940, joined efforts by other scientists to prod the United States government into preparing for nuclear warfare. Einstein played no other role in the nuclear bomb project. As a German who had supported left-wing causes, he was denied security clearance for such sensitive work. But during the war he did perform useful service as a consultant for the United States Navy's Bureau of Ordnance.

After the Japanese surrendered under nuclear bombardment, Einstein was often in the public eye. In May 1946 he became chairman of the newly formed, the Emergency Committee of Atomic Scientists, joining their drive for international and civilian control of nuclear energy. He recorded fund-raising radio messages for the group, and wrote a widely read article on their work. Einstein's appeals

Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

Einstein's Letter 1

-2-

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;

b) to speed up the experimental work, which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.

I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

Yours very truly,

A. Einstein

(Albert Einstein)

Einstein's Letter 2

for nuclear disarmament had an influence among both scientists and the general public. He also spoke out in opposition to German rearmament, defended conscientious objectors against military service, and criticized the Cold War policies of the United States. An early and firm supporter of the United Nations, he was convinced that the solution to international conflict was world law, world government, and a strong world police force. "I am opposed to the use of force under any circumstances, except when confronted by an enemy who pursues the destruction of life as an end in itself."

That brought him into conflict with people like Senator McCarthy and the FBI Director, J. Edgar Hoover. He angered them further when he urged intellectuals to refuse to testify before the McCarthy's House Committee on Un-American Activities.

From that moment on, he was considered a communist spy by the FBI and they kept him under constant surveillance. From the 1930's until his death, the FBI conducted a number of investigations to determine whether Einstein was a threat to the United States. Records of all these investigations run into more than 1,500 pages. Along with photographs and photocopies of some documents these files occupy several CD-ROMs.

These files chronicle attempts by non-government organizations in the U.S. to keep Einstein out and rumours of attempts by the Soviet Union to get him to move there, instead of United States. The files show that the Immigration and Naturalization Service investigated possible revoking of Einstein's citizenship in 1951, due to suspicion that his secretary and housekeeper was a Soviet agent.

The FBI investigation of his political activity concluded that Einstein was a member, sponsor, or affiliated with fifty communist fronts between 1937-1954. He also served as honorary chairman for three communist organizations.

The CDs contain, among others, 13 pages of letters Albert Einstein wrote to the U.S. Navy's Bureau of Ordnance, during 1943-44, that were related to the development of torpedoes and using mathematics in this process to maximize the impact of torpedoes against enemy ships. The letters include drawings and calculations Einstein made to illustrate his points.

On November 1, 1940 he was even interrogated under oath by the FBI. The interview was recorded. It was kept secret till recently. However, in 1981, biographical researcher Gene Dannen obtained a copy of it under the newly passed Freedom of Information Act. He has published excerpts from it though the original file is now in the public domain. Dannen has noted that the transcripts contain many errors that probably arose because Einstein's English was not fluent and the FBI agent interrogating him was not fluent in German. Still, Dannen's text, brief as it is, makes very interesting reading. Dannen reports:

AT PRINCETON, NEW JERSEY

Professor ALBERT EINSTEIN was contacted at his home 112 Mercer Street, and he advised that he has known LEO SZILARD since about the year 1920. He said that he believes SZILARD is a little over 30 [sic] years of age and was born in Hungary of Jewish parents. Professor EINSTEIN advised that he did not know

Office Memorandum · UNITED STATES GOVERNMENT

TO : Mr. D. M. Ladd

FROM : H. B. Fletcher

SUBJECT: Professor Albert Einstein
~~Security Matter~~
Internal Security - R

DATE: September 5, 1946

CONFIDENTIAL

Mr. Roach has learned from the Department of State that recently the American Ambassador at Moscow sent a report to the Department of State regarding an invitation extended to Professor Einstein to immigrate to the Soviet Union. This invitation, although official in nature, was, in fact, extended to Einstein by a Professor Kapitza. Professor Kapitza's invitation was in the form of a letter to which Einstein replied by a personal letter to Stalin. The United States Ambassador in Moscow stated that he was unable to check the veracity of the story but felt that it was highly significant in view of the fact that the reply given to Stalin showed the feelings amongst the Jews toward the Soviet Union. (X)

Professor Kapitza, under the direction of the Soviet Government, wrote a letter to Professor Einstein inviting him to come and work with Kapitza in the Soviet Union. Kapitza stated "in a land of true democracy, free from selfish taint," where they could pursue their scientific research unhampered by restrictions imposed by capitalist society. Einstein was assured that whatever funds, laboratories, buildings, equipment, books and assistants he might need would be immediately and completely placed at his disposal. (X)

Einstein's letter to Stalin was allegedly sent to Stalin through two Jewish members of a trade union delegation. These two representatives were received by Molotov. In his letter Einstein expressed appreciation of the offer but stated that before he could consider it he must ask several questions. His questions in substance were: Why are Jewish scientists not permitted to hold prominent posts? Why are apparently unnecessary obstacles placed in the way of Jewish scientific and research workers? Why were certain Jewish professors of medical science whose outstanding contribution to medicine not elected to the recently created Medical Academy? (X)

Molotov allegedly denied the truth of Einstein's allegations but again extended an invitation to Einstein to come to the USSR. It is stated that upon receipt of the complaints of Einstein, Molotov directed the Minister of Internal Affairs to immediately investigate the particular cases mentioned by Einstein. (C)

It is stated that as a result of these investigations certain high Soviet officials were discharged for anti-Semitism. The professors named by Einstein were then elected to the Academy. (X)

RECORDED 61-7099-6

In discussing this matter with State Department officials, Mr. Roach learned that the Department attaches considerable significance to this matter in view of the fact that it indicated to them that the Russians are attempting to obtain scientists such as Einstein from the United States and other countries who may have knowledge of atomic energy. (X)

66 OCT 2 - 1946

The above information is submitted believing it will be of interest to the Internal Security Section.

Note info ... Einstein's Secretary

CONFIDENTIAL

OK to release per State

The FBI report

anything about SZILARD'S relatives as he only knew him from a scientific point of view.

He further advised that LEO SZILARD was probably educated in Budapest, Hungary but that later in life he had spent most of his time in Berlin, Germany. He also stated that SZILARD had left Germany about the year 1933 and that he had spent sometime in England, although he, EINSTEIN, could not recall whether SZILARD had been in England prior to or after the year 1933. Professor EINSTEIN further related that SZILARD had made several trips to the United States in recent years.

He advised that SZILARD, while in Berlin, had been assistant to Professor LAUE at the University of Berlin. He said that Professor LAUE was a very decent man and that he is the only German he knows who behaved in an admirable way after Hitler's advent to power. Professor EINSTEIN continued that at the time SZILARD was at the University of Berlin he himself was at the Academy of Music [sic] in Berlin and he saw SZILARD every day for many years. He said that he did not believe that SZILARD had ever become a German citizen, although he was not positive of this.

In connection with the inventions SZILARD is supposed to have perfected with Professor EINSTEIN, the latter stated that he and SZILARD had been interested in the construction of a small cooling machine similar to our household refrigerators. He stated that they had worked together on this machine for sometime but had never completed it because of lack of money to finish it in its experimental stage. However, he advised that they had taken out *several patents on several parts of the machine. He stated that he did not know whether SZILARD might still be receiving royalties from these patents but said that he doubted very much whether SZILARD could be receiving any money from Germany at the present time. He said that SZILARD had some sort of an agreement by which he was to receive so much money from the Allgemeine Elektricituts Gefellichaft [sic] (A.E.G.). EINSTEIN said that this company would be known in America as the German General Electric Company.*

He went on to say that LEO SZILARD had left Germany about the year 1933 and that he believes SZILARD went to England and visited America on several occasions. He advised that at the present time SZILARD is connected in some manner with Columbia University in New York City, where he is working on uranium experiments for military purposes. He stated that this work is on a private scale but that it is financed by the University. He said that SZILARD is working with an Italian by the name of FERMI, who is a very trustworthy man. Professor EINSTEIN said that he sees SZILARD quite frequently as SZILARD visits him to inform him as to his work on the uranium experiment. He said that the last time he had seen SZILARD was a week or ten days ago, at which time SZILARD had visited him, together with Professor EUGENE WIGNER, of Princeton University.

Professor EINSTEIN advised that SZILARD is a theoretical physicist. He stated that SZILARD is a very idealistic man who is not at all politically minded. He stated that he had never been connected with any organizations, societies, or political groups *abroad. He said that SZILARD is a very fine, gifted young man; that he is absolutely honest, reliable, and trustworthy, and that he would recommend him very highly to the United States Government. Professor EINSTEIN stated that he would recommend SZILARD without any hesitation and that he would assume any responsibility for his conduct. He said that SZILARD is as anti-Nazi as he himself is and that SZILARD is an outspoken Democrat. He further advised that he believed the U.S. Government could trust SZILARD in any respect without any fear whatever that SZILARD might disclose confidential information to a foreign power.*

Professor EINSTEIN stated that Professor WIGNER was a very close friend of SZILARD'S and that SZILARD was also acquainted with Professor JOHN VON NEUMANN, 26 Westcott Road, Princeton, N.J. Of these two he believed that Professor WIGNER would know more concerning SZILARD.

Anyone who comes across this file may be laid to believe that one Albert Einstein was a rabid politician and a dangerous spy who was a threat to democracy and United States Government. The truth is totally contrary to it.

7
Where Is His Brain?

Death of a reigning monarch in tradition abiding England is announced with the expression, 'Long live the King; the King is dead'. The phrase conveys the sentiment that the particular sovereign is no more but the institution of monarchy survives and will live forever. The words thus are to be taken in a figurative and not a literal sense.

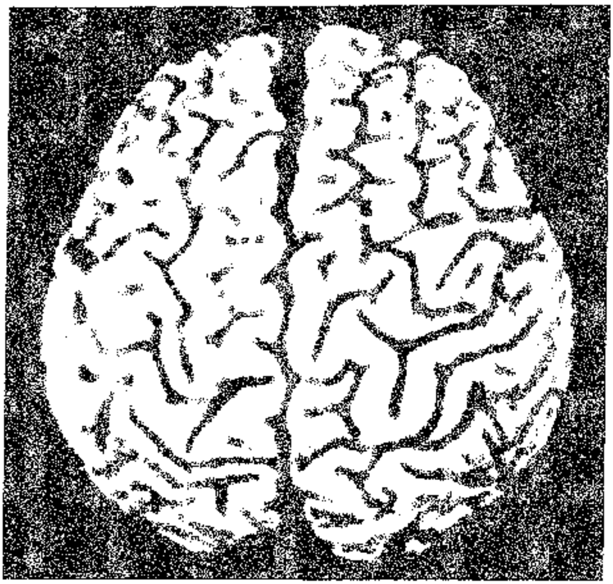
In Albert Einstein's case, however, such an expression has come to be literally true. Almost. Einstein is no more; his mortal remains too are consigned to flames long ago.

fell to forty-year old Dr. Thomas Harvey, the pathologist at Princeton Hospital. Dr. Harvey took it on himself to preserve Einstein's greatest asset – he cut a hole in Einstein's cranium and removed the brain.

The removal of Einstein's brain was solely Harvey's initiative. He did not know the feelings of the family on the matter. When a reporter asked him about it much later, he merely said: "I just knew we had permission to do an autopsy and I assumed that we were going to study the brain."

The family was kept in the dark. They came to know about the removal from a newspaper report the next day. One of Harvey's colleagues had spoken casually to a reporter about what was done at the time of autopsy. Even Otto Nathan, the executor of Einstein's literary estate who witnessed the dissection of his friend's body, had not realised what was going on. When he learnt about it he voluntarily contacted Harvey and gave his retrospective approval. Harvey said it was "just a misunderstanding".

Why the brain was preserved at all is not clear. Some commentators have claimed that Einstein himself wanted it to be used for research. This is certainly a misinterpretation. He had only talked vaguely about donating his body to medical institutions for study. There was no specific intent that his brain should be put under the microscope. However, there is no written record of this. Moreover, this is contrary to his confirmed desire that his body should be cremated. According to some biographers the decision to preserve the brain was made by Einstein's son. But the son's reaction, indeed that of the entire family, does not lend credence to this contention.



Einstein's Brain 1

Einstein's brain is no doubt a prized specimen for reasons that go beyond his superior intellect. For starters, his brain was in excellent shape when he stopped using it. Fate intervened by providing a sudden death, a ruptured aneurysm of the abdominal aorta. And, within 7 hours of his death it was already being removed from his skull. To prevent deterioration it was injected with, and then suspended in, formalin. Later, it was measured, photographed and cut into about 240 blocks, each about the size of a sugar cube. The blocks were embedded in celloidin and some were cut into sections for microscopic examination.

By then Dr. Harvey's enthusiasm petered out. Though he had initially vowed to carry out detailed anatomical and pathological investigations he did no such thing. The precious specimens were bottled and have been kept on a shelf in his offices. It is a surprise that the whole world forgot about its existence for the next 20 years. Einstein's brain would have continued to languish in that state but for the efforts of a persevering journalist, who went for some investigative reporting. Steven Levy, who was working for the magazine, *New Jersey Monthly*, was given an assignment by his editor. Levy was initially rather reluctant to pursue his project as he thought it to be a very uninteresting and unrewarding task. Little did he know then that he was about to land a big scoop. The story of his discovery is best read in his own words.

"A true story. It was 1978, and I was working for a regional magazine called *New Jersey Monthly*. It was located in Princeton. My editor told me to go find Einstein's brain. It seems that he had read the Ronald Clark's biography of Einstein and got to the part (towards the end, of course) where it says Einstein's body was cremated, except for the brain, which was kept for scientific study. Einstein had died in 1955 – twenty-two years before – and no one had heard squat about it since. My editor had tried to check up on it, even contacting the Einstein estate, but hadn't been about to find out anything about it. So he told me to do it.

"In short, I did. To make a longish story short (the story was published in the August 1978 edition of the magazine), I came to the conclusion that the brain, in sectioned form, was still in the possession of the pathologist who removed it from the Einstein head, Dr. Thomas Harvey. I tracked him down in Wichita, Kansas. At first he didn't want to tell me anything, but after a while he finally admitted that he had the brain. After a longer while, he sheepishly told me it was

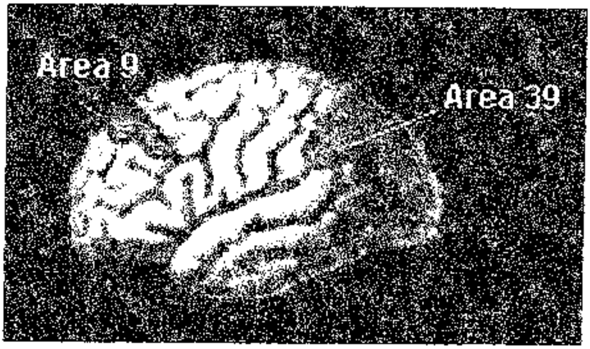
IN THE VERY OFFICE WE WERE SITTING IN. He walked to a box labelled "Costa Cider" and pulled out two big Mason jars. In those were the remains of the brain that changed the world. Forgive me, but it was almost a religious experience.

"After the article came out, the media went a little bonkers. They camped out on poor Dr. Harvey's lawn, and made life unpleasant for him. I did radio interviews for two solid days. Johnny Carson made a joke about it. My friends told me it would be the high point in my career. (Were they right? You decide.)

"Oh, and Dr. Harvey told me that so far he had found nothing to indicate the physical nature of this particular brain was anything special. But some scientists in California heard about the brain from my story and eventually did some work which showed some anomalies. Anyway, the big excitement for me was seeing those little brain-pieces, each the size of a Goldenberg's peanut chew, bobbing up and down in solution. That changed everything"

Levy was indeed right. His revelation about the existence of Einstein's brain was publicised very widely. In particular it did alert the scientific community. Availability of the brain tissue had suddenly offered a chance of learning the secret of his extraordinary intelligence. However, Dr. Harvey turned uncooperative. He adopted almost a dog-in-the-manger policy. Neither would he conduct any research himself nor would he allow anyone else an opportunity to do so. He did not categorically refuse any of the number of requests for a sample that poured in. But he did not part with any either.

Dr. Marian Diamond was the first to lay a hand on that valuable piece of tissue. She and her colleagues counted the number of neurons (nerve cells) and glial cells, which provide nutrition for nerve cells, in four areas of Einstein's brain: area 9 of the cerebral cortex on the right and left hemisphere and area 39 of the cerebral cortex on the right and left hemisphere. Area 9 is located in the frontal lobe, the prefrontal cortex and is thought to be important for planning behaviour, attention and memory. Area 39 is located in the parietal lobe and is part of the "association cortex." Area 39 is thought to be involved with language and several other complex functions. The ratios of neurons to glial cells in Einstein's brain were compared to those from the brains of 11 men who died at the average age of 64.



Brain Area - 1 a

The ratio of neurons to glial cells in Einstein's brain, as compared to those in the 11 normal brains, were smaller in all four areas studied. However, when the numbers were examined more closely with statistics, only one area showed a significant difference – the ratio in the left area 39. In that area, therefore, Einstein's brain had fewer neurons to glial cells than the normal brains. In other words, there were more glial cells for every neuron in Einstein's brain.

The authors concluded that the greater number of glial cells per neuron might indicate the neurons in Einstein's brain had an increased "metabolic need" – they needed and used more energy. In this way, perhaps Einstein had better thinking abilities and conceptual skills.

Marian Diamond had later described the extraordinary chain of events that motivated her to embark upon that research. Delivering a lecture at Doe Library on January 8, 1999, she said, "One day in my teaching laboratory, a world renowned professor of neuroanatomy, Professor Gerhardt von Bonin, mentioned that he thought the inferior parietal cortex was more highly evolved than the parietal cortex. The idea was contrary to what is normally accepted. Since the number of glial cells per neuron increases as one ascends the phylogenetic tree, I reasoned that the more highly evolved area in the human brain should have more glial cells per neuron.

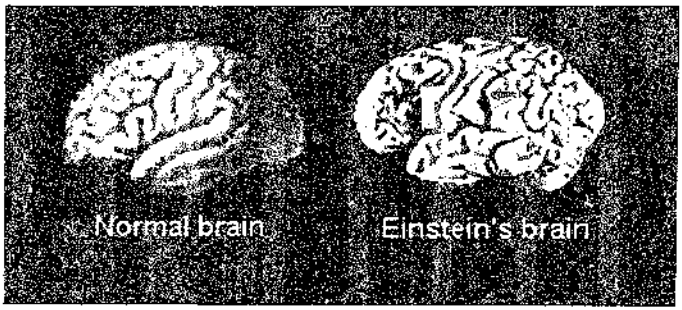
"From 11 human, male, preserved brains, I removed a sugar cube-size piece from right and left prefrontal and inferior parietal cortex, giving 44 samples. Thus we had a database of human cortical glial/neuron ratios. We learned the frontal cortex did have more glial/neuron than the parietal cortex.

"In the early 1960s, the laboratories, both of Joseph Altman at Purdue and ours, had found that the cerebral cortex from rats living in enriched environments had more glial cells per neuron than the cortex from rats living in impoverished environments. Active cortical neurons needed more support cells.

"The graduate students had clipped a photo of the box with Einstein's brain from *Science* magazine and attached it to the laboratory wall. The caption mentioned that the brain was in Kansas. A daily exposure to its message was available for all who entered the laboratory.

"I was sitting by myself in my husband's office at UCLA one day with nothing to do but think. I wondered if I could obtain only four pieces of Einstein's brain comparable to the ones already studied. I picked up the phone and called the University of Kansas Department of Anatomy and learned that a Dr. Thomas Harvey, in Missouri, had Einstein's brain. Why he took the brain to Missouri I do not know. Who was Thomas Harvey? He was the pathologist at Princeton at the time of Einstein's death. He had had the keen foresight so that when Einstein died, Harvey fixed his brain rapidly in formaldehyde to preserve the nerve cells before they disintegrated. Twenty-five years later I began negotiating by calling Thomas Harvey in Weston, Missouri every six months for about three years before I received the four precious blocks of tissue in my mail box in the Life Sciences Building. When the package first arrived, the only person in the office was the office manager. I said rather breathlessly, "Guess what I have here in this box, Jerry?" He sort of gave me half of his attention and when I said "parts of Einstein's brain," he replied, "Oh, come on Marian." Believe me, after that when I asked him what I had received in the mail on another day, he certainly gave me his full attention.

"In a mayonnaise jar filled with fluid, here were my four sugar cube-size pieces of Einstein's brain. Evidently, Harvey had cut up the brain and embedded the pieces in a substance called celloidin, which hardens almost like plastic. Having the brain in this condition was ideal for my purposes because we wanted to count cells under the microscope. To do this, it was necessary to make thin slices, 6 micron in thickness (a micron is one thousandth of a millimetre). In order to cut at this precise level of thickness, the tissue had to be processed in celloidin. Preserving the brain in this manner, however, does not allow for some other methods of examination such as refined chemical analysis. We were extremely fortunate to have the tissue preserved in a way that proved ideal for us. We had our 44 pieces of brain from the 11 normal males.



Einstein's brain 2

We could now compare the glial neuron ratios in the 4 pieces from Einstein's brain with the 44 pieces from the normal males. With the help of an excellent technician and statistician (a scientist rarely works alone), we learned that in all four areas, Einstein had more glial cells per neuron than the average man, but in only the left inferior parietal area did he have statistically significantly more."

Though the observations made by Diamond and her colleagues were significant, other scientists were not convinced of their interpretation. They found a number of shortcomings in the study conducted by her.

First, the "normal" brains that were compared to Einstein's may not have been the best group for comparison. The average age of these brains was 12 years younger than Einstein's brain. In fact, the youngest brain in this group was only 47 years old. It is possible that the neuron to glial ratio seen in Einstein's brain was quite normal for his age and that the younger comparison group just did not show these changes yet. Also, the paper did not describe the background of the comparison group. What was their intelligence and cause of death? Would these factors have anything to do with the observed brain differences?

Second, the "experimental group" had only one subject...Einstein! Additional studies are needed to see if these anatomical differences are found in other people with conceptual and mathematical skills like Einstein.

Third, it appears that only a very small portion of the four areas of each brain was studied. The paper states, "Four to six sections were cut from each block, Einstein's and the controls'." However, after staining, only ONE section from each block was studied! There is no indication that this single thin section was obtained from similar regions of area 39 and area 9 from the different brains. It is even unclear how much of each section was counted. Moreover, only the ratio of neurons to glial cells was published. The total number of cells that were counted is not given in the paper. This is important to get an idea of how the experimenters came to their conclusions.

Dr. Diamond's research, nonetheless, whetted the appetite of other scientists to look at this extraordinary piece of human tissue. They wanted to pursue other studies to discover the secret of Einstein's intelligence. They kept contacting Harvey who had gone back into his shell and was not responding.

But Sandra Witelson from the McMaster University of Canada turned out to be very lucky. She was approached by Harvey himself, asking whether she would be interested in studying Einstein's brain.

It so happened that Harvey was suddenly shaken out of his inertia. In 1993 he gave Dr Britt Anderson from the University of Alabama, a small sample from the cortex of Einstein's brain. Cortex is the part of the brain where higher thinking takes place. He packed it in a plastic bag with a zip-lock and mailed the specimen. But it got lost in the mail. After both Anderson and Harvey lodged complaints an intensive search was undertaken and the parcel traced.

Anderson found that the cortex was thinner but appeared to be more densely packed with cells. She could not decide if this was unique to Einstein, unless he could compare his observation with that on brains of other normal individuals. So he went back to Harvey and suggested that they should approach Sandra Witelson, who had with her a large collection of brains of people more than 40 years old.

Agreeing to her suggestion, Harvey contacted Dr. Witelson. She could not believe her good fortune. For her, this was an unexpected windfall. She was not the one to look in the mouth of a gift horse. She readily agreed. Having had the harrowing experience of losing the specimen in the mail, this time Harvey decided to deliver the sample personally. So he drove north towards Canada dumping the bottles containing the precious brain tissue unceremoniously in the dicky of his car.

At the Canadian border he approached the customs officials and declared that he was carrying some special goods. But the dumb bureaucrats there squandered the once-in-a-lifetime opportunity of setting their eyes on that very special cargo. They merely took Harvey's word for it and waved him off.

Merely holding that prized brain in her hand, nonetheless, overwhelmed Witelson. She lost no time getting down to work. She had learnt from Harvey that Einstein's brain weighed only 1,230 grams, which is less than the weight of average adult male brain, which is about 1,400 grams. She then measured the thickness of Einstein's cerebral cortex. This was lower than that of five control brains. However, the density of neurons in Einstein's brain was greater. In other words, Einstein was able to pack more neurons in a given area of cortex.

She went on to compare the external surface characteristics of Einstein's brain with those from the brains of 35 men (average age, 57 years old). Unlike the brain of these 35 men, Einstein's brain had an unusual pattern of grooves (called sulci) on both right and left parietal lobes. This particular area of the parietal lobe is thought to be important for mathematical abilities and spatial reasoning. Einstein's brain had a much shorter lateral sulcus that was partially missing. His brain was also 15% wider than the other brains. The researchers think that these unique brain characteristics may have allowed better connections between neurons important for mathematics and spatial reasoning.

This finding attracted the attention of Dr. Michael Gazzaniga, Director of the Centre for Cognitive Neuroscience at Dartmouth College in Hanover. He believes that how brain cells are networked together is more important. In most brains, the Sylvian fissure, a groove that runs along both sides of the human brain from front to back, divides the area that deals with mathematical reasoning from the area that deals with visual and spatial connections. But in Einstein's brain, that division doesn't exist. That could have allowed neurons from the two areas to network more efficiently.

Witelson's conclusion that Einstein might owe his intelligence to this peculiar feature of his brain appears to be substantiated by Einstein's own description of his way of thinking. Appreciative that there was something special about the way his brain worked, Einstein had gone out of his way to help fellow scientists unravel the mystery by consenting to an electroencephalograph examination, that recorded his brain wave activity. He also consented to interviews in which he explained how he solved problems. His explanation was quite extraordinary. "Words do not seem to play any role," he once said. "There are more or less clear images."

Again, these findings are not conclusive. They do take us a step further but still leave a number of unanswered questions. The brain of a genius reveals some, but not all, of the qualities that made him special.

That, nonetheless, is not the end of this weird story. It took another bizarre twist in 1997. By then Harvey, who had moved around the country, had settled in New Jersey. He had always carried the bottles containing the brain with him wherever he went. That year he suddenly decided, for no apparent reason, to return that prize possession to what he considered its rightful owners. He found that Einstein's granddaughter lives in Portland, Oregon, on the west coast of US. So, he decided to go there. A freelance writer, Michael Paternity, volunteered to drive him there. So they set out on a long coast-to-coast journey of some six thousand kilometres. They had several interesting and colourful events along the way. When they reached Einstein's granddaughter, she had a good look at those remains of her grandfather but refused to take possession of his 'soul'. She returned the tissues to Harvey. He had no other choice but to bring them back to his residence on the other coast. Paternity has written a humorous but compassionate account of their travels in the book, *Driving Mr. Albert: A Trip Across America With Einstein's Brain.*

Now, in 2005, half a century after it was sliced into 240 pieces, a team has created a life-size replica, which, it believes, could shed new light on one of the greatest scientific minds.

This year, 2005, scientists are commemorating the 50th anniversary of Einstein's death and the 100th anniversary of his intellectual flowering. In 1905, his then 26-year-old brain helped to redraw our understanding of energy, matter, motion, time and space.

Dr Mark Lythgoe of University College, London, and Icon Films have marked the milestones by reconstructing the great man's brain. "When I examined it, I felt as if I had climbed to the top of a mountain and enjoyed a view – one of intellectual creativity – that has never been seen before," says Lythgoe.

8
Man Of The Century

A good many stories and anecdotes are always told about every famous person. Many of these are of doubtful veracity but make delightful reading. Some of these emanate from people who had known the superstar fairly intimately or had interaction with him during their professional activities. Those stories may have a grain of truth. It is possible, though, that even these might get laced with the individual raconteur's own desire to bask in reflected glory. Nonetheless, these anecdotes quite often shed light on those facets of the celebrity's personality that had stayed away from public gaze.

Stories about Einstein also bring to light that unknown side of his personality. He has often been portrayed as an intellectual loner who could not suffer fools gladly. Some have even suggested that he was ill at ease in the company of those who could match his intellect. But all the anecdotes told about him indicate that he had considerable human warmth, wit and unpretentious manner that enabled him to engage into entertaining conversations with ordinary folk.

David Rothman who owned a family department store in a small town had personal experience of it. In the summer of 1939, Albert Einstein spent his summer on Nassau Point, in Peconic, New York State on eastern Long Island. One June day, Einstein came into the store. Of course, Rothman recognized him at once. He decided, though, to treat him just like any other customer.

"Are you looking for something in particular?" he asked.

"Sundials," Einstein said in his thick German accent.

Now, Rothman's has always had a large variety of items – just about everything from house wares, to fishing tackle and bait, to hardware, to toys, to appliances. But no sundials. Not for sale, anyway. But...

"I do have one in my back yard," Rothman said.

He led Einstein, who seemed a bit bewildered, to the back yard, to show him the sundial. "If you need one you can have this."

Einstein took one look and began to laugh. He pointed to his feet. "No. *Sundials.*"

"Sandals!" Rothman exclaimed. Those, he had.

As he was packing the merchandise, Einstein, heard the classical music playing on the record player. Suddenly Rothman remembered that Einstein played the violin. So did Rothman and told his customer about it.

Einstein's face immediately lit up. "We must play together some time." He said.

They set a date. As Rothman prepared for the session, he wasn't sure which music to bring, and finally decided on an assortment from simple to a Bach piece that was the most difficult thing he had ever played. When he arrived at the summer cottage Einstein had rented (still referred to as "The

Einstein House"), he was welcomed warmly. Einstein looked over the music and chose the Bach.

They began to play. It was obvious quite quickly that Rothman was out of his league; Einstein was just too good. After a couple of minutes, Einstein set down his violin and said, "Let's talk instead."

The rest of the evening was spent out on Einstein's front porch, just talking. Rothman had only grade school education, but was intensely interested in science and philosophy, and the two men found they had some common ground.

After several hours, Einstein's housekeeper came out and scolded Rothman.

"You are keeping Dr. Einstein awake," she said.

"No," Einstein said. "I am keeping *Mr. Rothman* awake."

Any one who came in contact with Einstein was usually awed by his presence unless, of course, he had not heard of him, which would be a rarity. But Einstein had a way of putting the other person at ease. He would brush aside his superstar status and make light of it. Asked once about it he exclaimed "the ladies of New York want to have a new style every year. This year the fashion is relativity." On another occasion, he was introduced to the eighteen-month-old son of a young friend. The infant looked into the old physicist's wizened face and promptly began to bawl.

"You're the first person for years," Einstein declared, patting the child on the head, "who has told me what you really think of me."

In 1933, the year of Hitler's formal rise to power, Jewish scientists were fired *en masse*. Half of Germany's theoretical physicists lost their jobs. Hitler cared little about the consequences. "If science cannot do without Jews," he told the physicist Max Planck, "then we will have to do without science for a few years." Einstein too fled Germany. Despite his bravado Hitler seemed to have been stung by that rebuff from such an eminent scientist. So Shortly thereafter one hundred Nazi professors published a book (*One Hundred Authors Against Einstein*) condemning his theory of relativity. Einstein's rejoinder was characteristically modest and witty. "If I were wrong," Einstein said, "one professor would have been enough."

This humility made him enjoy the company of children who, not really knowing his pre-eminence, were never overwhelmed by his presence. A five-year-old boy, a neighbour of Einstein, grew fond of him and would often stop him for conversation as Einstein went back and forth past the little boy's house. One day, while the two were in deep conversation, Einstein suddenly burst into laughter. That night the youngster's mother asked him what was so funny. The boy replied, "I asked Einstein if he had gone to the bathroom today." The mother, quite shocked, asked what Einstein answered. He said, "I am glad to have someone to ask me a question I can answer."

One day in his twilight years, he received a letter from a 15-year-old girl asking for help with a homework assignment. She soon received a curious reply: a page full of unintelligible diagrams, along with an attempt at consolation: "Do not worry about your difficulties in mathematics," Einstein told her. "I can assure you that mine are much greater!"

Sometime, however, such pranks backfired. One story of such an incident apparently concerns Albert Einstein's driver on a particular lecture tour. It seems that he used to sit at the back of the hall during each of his lectures, and after a period of time, remarked to Einstein that he could probably give the lecture himself, having heard it several times. So, at the next stop on the tour, Einstein and the driver switched places, with Einstein sitting at the back of the hall, in driver's uniform.

The driver gave the lecture, flawlessly. At the end, a member of the audience asked a detailed question about some of the subject matter, upon which the lecturer replied, "Well, the answer to that question is quite simple, I bet that my driver, sitting up at the back, there, could answer it."

Even when he migrated to the US and was offered a lifelong position at the renowned Institute of Advanced Studies at Princeton he retained his modesty. The chief of administration was nonetheless quite flustered by the arrival of the genius. He naturally wanted to make him feel totally at home. So he asked gently what equipment Einstein needed. Pat came the reply, "A desk or a table, a chair, paper and pencils. Oh yes, and a large waste basket, so I can throw away all my mistakes."

Theoretical physicists today need powerful computers to carry out complicated calculations. But in Einstein's days all that was available to such scientists was pen and paper or blackboard and a chalk. And a mind that could cogitate over the problem in hand, in any surrounding.

Einstein himself made this quite clear in a self-deprecating way once. Before visiting the Berlin Astrophysical Observatory one day, Albert Einstein and fellow physicist Philip Frank agreed to meet on a certain bridge in Potsdam. When Frank hesitantly mentioned that he may perhaps be late, Einstein told him not to worry; he would simply wait on the bridge.

Frank then expressed concern about wasting his colleague's time. "The kind of work I do can be done anywhere," Einstein replied. "Why should I be less capable of reflecting about my problems on the Potsdam bridge than at home?"

On the other hand, he could not stand pompous people and was very curt with them. Several anecdotes reveal this. "Two things are infinite," he once declared, "the universe and human stupidity; and I'm not sure about the universe.

A beautiful young American girl who, defending discrimination, had asked Einstein, "What would you say if your son announced he was going to marry a Negress?"

He replied, "I should probably ask to meet his fiancée. But if my son announced he wanted to marry you, I should certainly lose both sleep and appetite."

Once some reporters from Boston trying to rattle him asked, "What is the speed of sound?"

"I don't know offhand," he replied. "I do not carry information in my mind that is readily available in books."

He was visited one day by one of his students. "The questions on this year's exam are the same as last year's!" the young man exclaimed.

"Yes," Einstein replied, "but this year all the answers are different."

It is said that when his theory of relativity was published there were less than a dozen people in the world who could understand it. Einstein himself was acutely aware of its complexity. *Scientific American* once ran a competition offering several thousand dollars for the best explanation of Albert Einstein's general theory of relativity in three thousand words.

"I'm the only one in my entire circle of friends who is not entering," Einstein ruefully remarked. "I don't believe I could do it."

Still he firmly believed that "You do not really understand something unless you can explain it to your grandmother." That is why he made several attempts to express his ideas in simple words that anyone can easily comprehend. On one occasion he said, "Two hairs in my cup of milk is too much. Two hairs on my head is too less. That is relativity."

On another, he had another explanation. . "Put your hand on a hot stove for a minute, and it seems like an hour," he declared. "Sit with a pretty girl for an hour, and it seems like a minute. That's relativity!" He even tried to explain the operating principle of a wireless telegraph in a very amusing manner. "The wireless telegraph is not difficult to understand. The ordinary telegraph is like a very long cat. You pull the tail in New York, and it meows in Los Angeles. The wireless is the same, only without the cat."

Modest otherwise, when it came to his theories Einstein was quite obdurate. One day, one of his assistants expressed his joy that experimental results had confirmed the General Theory of Relativity. "But I knew that the theory was correct," Einstein calmly remarked.

The assistant then asked what he would have done had his predictions not been confirmed. "Then," Einstein replied, "I would have felt sorry for our dear Lord – the theory is correct."

Such strong views brought him into conflict with other equally eminent physicists of his time. Despite Werner Heisenberg's Nobel Prize in 1932 for its formulation, Einstein never accepted the so-called "uncertainty principle", which stipulates that the more carefully one measures the position of a given particle, the less certain its momentum becomes, and *vice versa*. He could not quite accept that because it threatened to wreak havoc with the strict determinism in which he believed. He expressed his rejection of that hypothesis in very colourful words. "God," he often declared, "does not play dice with the universe."

"Who are you," Niels Bohr once retorted, "to tell God what to do?" Years later Stephen Hawking also entered the fray: "God not only plays dice," he declared, "but sometimes throws them where they cannot be seen."

Because of these unyielding positions Niels Bohr and Einstein engaged into one of the most celebrated and heated scientific debates of all times. Bohr, of course, won it but not before Einstein himself provided the evidence in his favour. On one memorable occasion, at the Solvay conference in Brussels in 1930, Einstein unveiled the product of one of his famous "thought experiments": an imaginary device comprised of clocks and scales, which, he claimed, violated the principle.

Following a sleepless night, however, Bohr discovered that Einstein had made a critical error: he had neglected to take into account the fact that clocks run slower in a gravitational field... a consequence, rather ironically, of Einstein's own theory of relativity!

That only goes to show that he was very much human.

Notwithstanding such violent differences Einstein was very friendly with other scientists and also earned their respect. He was not averse to playing some pranks with them. While working with fellow physicist Abraham Pais at the Princeton Institute for Advanced Study one evening, Niels Bohr, who was in the habit of repeating words over and over whenever he was engrossed in thought, began pacing around the office, repeating, "Einstein... Einstein..."

Suddenly Pais noticed the office door begin to open and Einstein himself tiptoed into the room; Bohr, standing at a window with his back to the door, did not see his colleague come in. "Then," Pais later recalled, "Einstein beckoned to me, with his finger on his lips, to be very quiet, his urchin smile on his face." Silently, he made a beeline for the table at which Pais was sitting. Finally Bohr, still muttering Einstein's name, turned around – and was astonished to find the object of his thoughts had apparently materialized before his eyes.

All three men stood and stared at one another, until Einstein explained why he had come: Smoking was against his doctor's orders and he had promised not to buy tobacco. He had, however, never promised not to steal tobacco – as he was presently doing from the large pot, which was resting on the table. Einstein got his tobacco and all three men promptly burst into laughter.

John Kemeny, a brilliant mathematician and computer pioneer who worked for Einstein from 1948 to 1949, relates a joke that must have been one of Einstein's favourite, because Einstein repeated it more than once. A man goes to have his car repaired. The mechanic looks at everything and then he kicks the car. After which it runs perfectly. The owner is terribly happy until he gets a bill for $25, which in the late 1940s was outrageously large. He complains bitterly and asks for an itemized bill. So the mechanic writes out the bill: Labour: kicking the car - 25 cents; Knowing where to kick - 24 dollars and 75 cents. It is easy to understand why Einstein would like that story. It's not the kicking that counts, but knowing where to kick.

Does that make him a very complex individual? Hardly. As his friend and biographer Philip Frank sums up, he was a very compassionate person who was able to view everyday life in comic light. That is why his casual interactions with common people were always a mixture of light-hearted banter and jokes, which made the other person, feel equal to him. He did not assume a position on a pedestal looking down at his companion of the moment. That is what warmed the cockles of many an individual. No wonder when *Time* came to decide he was voted 'Man of the Twentieth Century.'

Epilogue

Albert Einstein told us that to precisely place an object in this universe the three spatial dimensions are not enough. The fourth dimension of time is equally necessary. It is not enough to know 'where'. It is also necessary to know 'when'. The precise location of an object, like an individual, for example, can be determined only by knowing his or her coordinates along all the four dimensions.

In order to get to know that individual, however, one more, the fifth dimension of his personality, his inner self is also necessary. How does that individual conduct himself in various surroundings, under various circumstances, in response to different stimuli or experiences? It is necessary to understand that so as to get to know that individual.

The coordinates, along that fifth axis, of Albert Einstein are before us now. They have arguably given us a little better perception of this towering personality.

Even so, this is not the end of the story. Most certainly not. On the contrary, it is just the beginning. A few doubts have been cleared. Some light has been shed on a few facets that had so far remained in the dark. Still, a number of new questions have arisen in the mind. They are crying for answers.

That is how it should be. A scientific quest is always unending. Einstein did provide answers to some of the intriguing questions that had been troubling scientists, indeed the whole of mankind, for a long time. Even so, he would be the last to claim that no more mysteries remain unsolved; no more peaks remain unconquered. Even as one stands puffing on a peak that has been painstakingly climbed several new ones that are covered in the surrounding mist come into view. Their veiled countenance beckons one on yet another adventure. It is like the legendary walk to the horizon. Even as one thinks that one has finally reached the horizon one realises that the horizon is as far away as it ever was and ever will be. That is the beauty and allure of all such quests.

So it would not do to spoil it all by saying that the final word is now known. One would not like to deprive oneself of the joy of the unknown. Let that darkness keep beckoning us so that we continue to undertake that journey to the land where no one has gone before. There could be a whole new dimension to explore.

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Most famously known for his theory of relativity and the path-breaking equation $E = mc^2$, Albert Einstein remained an enigma during his lifetime. Even after his death his brain remains a source of wonder for neurologists. What was this man like in his real life? Chosen as the Man of the 20th Century by *Time* magazine, Einstein was a genius, but he had his eccentricities too. He was also a statesman and even held a patent for his invention. Replete with anecdotes, this book is an attempt to bring out these and many other little-known facets of Einstein's personality.

Bal Phondke (b. 1939) is a popular science writer par excellence, whose columns are featured in almost all leading Marathi newspapers. A recipient of several prestigious awards including the NCSTC National Award for Best S & T Coverage in the Mass Media, INSA Indira Gandhi Prize for Popularisation of Science and B.C. Deb Memorial Award of the Indian Science Congress Association. After obtaining doctorate in biophysics-immunology from London University, he began his career as a research scientist in BARC. He rose to become Chief Editor of Science Today, science editor of the Times of India group of newspapers, and later Director of National Institute of Science Communication (CSIR). He continues to be a prolific freelance science communicator. He has published so far over 40 books in Marathi, English and Hindi.

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