**Albert Einstein** – (b.1879 – d.1955)

Achievements at a Glance

In 1905, he conceived light quanta, special relativity, and statistical methods for showing the existence of atoms.

From 1915-1917, he generalised relativity, found the field equations for gravity, found a physical explanation for light quanta, hinted at how the quanta involved probability rather than certainty and came up with a concept for the universe as a whole.

Childhood (1879 – 1896)

* Einstein was slow to speak.
* He was fascinated by a compass.
* He played the violin and loved Mozart.
* Excelled in school, particularly math and physics.
* Was tormented a little in school by bullies.
* Was intellectually stimulated by Max Talmud as a child and introduced to Aaron Bernstein’s, *People’s Books on Natural Science*, and Euclid’s math principles, and philosophy, especially Kant and Hume.
* At 12 Einstein rebelled against Judaism.
* At 15 his family moved to Italy leaving Einstein to finish his schooling, but at Christmas he left Munich and renounced his German citizenship.
* Studied for the Zurich Polytechnic but, despite easily passing the math and science sections, failed the general section. So he spent a year studying at Aarau, while boarding with the Wintelers. He started a relationship with the daughter, Marie. The father helped shape Einstein’s liberal views about politics, world federalism, pacifism and so on. At the end of the year, he scored the second highest grades in his class and performed the best on the Zurich Polytechnic entry exam.

The Zurich Polytechnic (1896-1900)

* Taught by Heinrich Weber who he liked at first but became disenchanted with because he refused to teach recent advances, such as James Clerk Maxwell’s electromagnetic wave theory.
* He disliked the practical and experimental side of physics as well as the mathematical side.
* Was taught by Hermann Minkowski in maths. He called him a “lazy dog”.
* Met Marcel Grossman who helped him with the maths.
* He befriended Michele Besso who would remain one of his closest friends.
* Developed a taste for Bach, Schubert and, of course, Mozart.
* Broke up with Marie and started dating Mileva Maric.
* In his intermediate exams he finished first. To graduate, he had to do a research thesis. He proposed one on the speed of the Earth through the Ether which Weber rejected, then one regarding electricity which Weber also rejected. He ended up doing one on heat conduction, Weber’s speciality, which Einstein hated. He scored one of the lowest grades in the class but still graduated.

The Lovers (1900-1904)

* His parents didn’t accept Mileva.
* He couldn’t get an academic job anywhere.
* In Feb 2001 he became a Swiss citizen.
* He couldn’t get a job (possibly because of Weber) so he moved in with his parents in Milan, where his father wrote a letter to a professor on his behalf, to no avail.
* Grossman got Einstein a job at the Swiss Patent Office in Bern.
* Maric gave birth to Lieserl out of wedlock in 1902. Einstein would never see her. She was eventually adopted possibly to a friend of Maric.
* Formed the Olympia Academy with Maurice Solovine and Conrad Habicht.
* Married Mileva in Jan 1903.
* Hans Albert Einstein was born in May 1904.

The Miracle Year (1905)

Light Quanta (March 1905)

* “Blackbody” radiation measures the intensity of wavelengths emitted when a material is heated. But no one could mathematically describe the results. Planck found a way using a strange little constant (Planck’s constant), which he posited was a fixed amount of a packet of energy absorbed or emitted when a wave interacted with matter.
* Philip Lenard found the photoelectric effect where electrons emitted had more energy as the light frequency increased from infrared and red to violet and ultraviolet. Light intensity had no effect. The wave theory of light couldn’t explain this.
* Einstein took Planck’s quantum interpretation and quantized light. He then explained blackbody radiation (by showing the radiation emitted was equivalent to a gas of particles) before applying it to Lenard’s photoelectric effect.
* This was highly revolutionary and wasn’t accepted for many years afterwards.

Doctoral Dissertation of the Size of Molecules (April 1905)

* It was known that any equal volume of gas, at the same temperature and pressure, will have the same number of molecules. The standard was 22.4 litres at standard temperature and pressure and the number of molecules was called Avogadro’s number. But how many molecules was this?
* Previous measurements had been made using gases but Einstein used liquids and viscosity to derive a figure.

Brownian Motion (May 1905)

* This describes the situation where small particles suspended in a liquid are observed to jiggle around.
* Scientists knew of molecules from gas studies, but the suspended particles were 10,000 times larger than water molecules so they couldn’t be responsible. Einstein realised that millions of molecules striking particles would force it into a staggering “walk”. Einstein calculated precise predictions showing the distance a particle should move depending on its size and the temperature of the liquid. Months later, a researcher confirmed Einstein’s predictions.

Special Relativity *On the Electrodynamics of Moving Bodies* (June 1905)

* The paper contained no citations, no references and no acknowledgments except to Michele Besso.
* Only refers to inertial reference systems (uniform movement in a straight line at a steady speed) and measurements made between such systems relative to each other.
* Galileo understood relativity as long ago as 1632. It held that between two inertial reference frames there is no way to know which is moving and which is stationary.
* The speed of light was found to be 186,000 miles per second. The question was relative to what? Scientists proposed an ether which light waves ‘waved’ in the same way that sound waves ‘waved’ air. Unfortunately, nobody could find it.
* Einstein imagined riding alongside a beam of light at the same speed and reasoned he would see a stationary wave spatially oscillating, but there’s no such thing either in experiment or according to Maxwell’s equations. Actually an ether theorist could imagine a frozen light wave but it violated Einstein’s intuition.
* Albert Michelson and Edward Morley’s famous experiments found no ether and found no difference in the observed speed of light no matter which direction the observer is moving.
* Two postulates; the principle of relativity (all fundamental laws of physics are the same for all inertial reference frames i.e. observers moving at constant velocity relative to each other cannot determine who is moving and who is stationary) and the light postulate (the speed of light is constant).
* After his postulates came “the step”. There is no absolute time; all moving reference frames have their own relative time. (Ernst Mach and Henri Poincare both helped this thrust by lambasting Newton’s theory of absolute time) Specifically, two events that appear to be simultaneous to one observer will not appear to be simultaneous to a rapidly moving observer, and there is no way to declare that one of the observers is correct. Use lightning bolts striking on a train track example.
* Some consequences of special relativity. Space and time are also relative. Time dilation which says that time goes more slowly on the train than for the observer on the bank. (Use ‘clock’ mirror example for this). As an object approaches the speed of light, its apparent mass will also increase because more force (F=MA) will produce less and less acceleration.
* Note that it’s not a question of whether rods actually shrink or time actually slows down, all we know is that observers in different states of motion measure things differently and none of them are *correct*. All inertial frames are equally valid.
* Special relativity says that the measurements of time (including duration and simultaneity) can be relative depending on the motion of the observer. So can measurements of space, such as distance and length. But there is a union of the two, spacetime, which remains invariant in all inertial frames. Likewise there are things, such as the speed of light, which remain invariant.
* Hermann Minkowski gave special relativity a more complicated new mathematical structure in 1908, which revealed the intertwined nature of space and time. Einstein joked that, “Since the mathematicians have grabbed hold of the theory of relativity, I myself no longer understand it.”

The E=mc2 coda (September 1905)

* With 3 pages Einstein realised that energy and mass were related after considering special relativity with Maxwell’s equations.

The Happiest Thought (1906-1909)

* Einstein’s papers didn’t create much of a stir although Max Planck became interested. He still couldn’t get a teaching position.
* In 1907, he realised that if a person falls freely he will not feel his own weight. This was the ‘happiest thought’ and the myth later sprung up that he came up with it watching a man fall off a roof. Next he imagined a person in a freely falling elevator who will feel no gravity. Then he imagined the elevator in a gravitationally free space was being pulled upwards. The man inside would think he is in a gravitational field. Scientists had long known about the *inertial mass* and *gravitational mass* which, while being defined in different ways were always the same. Einstein didn’t like this. This led to his *equivalence principle*.
* By 1908 academic stars like Max Planck were writing to Einstein.

The Wandering Professor (1909-1914)

* Einstein started teaching at the Zurich Polytechnic.
* In July 1910, Einstein had another son, Eduard (Tete). He suffered terribly as a child and had a lot of health problems.
* In 1911, he moved to the University of Prague. This allowed Einstein to meet two of his scientific heroes, Ernst Mach and Hendrik Lorentz. Einstein idolised Lorentz. Maric was unhappy about the move to Prague.
* At this time he met Paul Ehrenfest and they became good friends.
* Einstein became reacquainted with Elsa Einstein (his cousin, divorced with two children) and began flirtations with her.
* Einstein moved back to Zurich in 1912. He was now earning a lot of money and was becoming quite famous in scientific circles. Maric’s depression continued to worsen.
* In 1914, Einstein accepted a non-teaching position in Berlin at the Prussian Academy of Sciences. Maric hated it and they separated later that year. She took the boys back to Zurich. Einstein paid her almost half his salary.

General Relativity (1911-1915)

* Einstein’s special relativity was incomplete in two ways. One, it said nothing can propagate faster than the speed of light which was incompatible with Newton’s theory of gravity which conceived of gravity as a force that acted instantly between objects. Second, it didn’t account for accelerated motion. He needed a new field theory of gravity and to generalise his relativity theory.
* Starting from his equivalence theory he realised that gravity should bend light. He also realised that he would need non-Euclidean geometry but that was a little beyond his capabilities at this stage so he enlisted his old friend Marcel Grossman.
* Grossman identified Bernhard Riemann’s metric tensors which is a mathematical tool which tells us how to calculate the distance between points irrespective of the contortions of that space. The useful thing about Riemann’s tensor, and others that Einstein and Grossman used, were that they were *generally covariant*.
* Einstein had two goals in mind; 1, how a gravitational field acts on matter and, 2, how matter generates gravitational fields in spacetime. The big insight he realised was that gravity was the curvature of spacetime.
* In May 1913, Einstein and Grossman produced a paper known as the *Entwurf* but Einstein soon had misgivings about it. One big hint that it was incomplete was that it didn’t solve the anomaly in Mercury’s orbit.
* Einstein fixed as many of the problems he could and in June 1915 delivered a series of two hour lectures explaining it. David Hilbert was present and decided that he could finish the theory completely. Einstein realised this and a great race started. Einstein returned to Riemann and Ricci’s tensors and after an exhausting four week frenzy, he delivered a flurry of four lectures over as many weeks to the Prussian Academy. It climaxed with the triumphant revision in November 25, 1915.
* In the third of these four lectures Einstein revealed that his equations solved the Mercury orbit problem. This discovery was one of the emotionally strongest moments in his life.
* Hilbert actually gave his talk on Nov 16 and dated the final paper Nov 20 and Einstein delivered his final analysis Nov 25, but it seems that Hilbert had to revise his equations and amended them with the phrase, “first introduced by Einstein”. The revised equations were sent to the publisher on Dec 25. It’s a slightly moot point however because Hilbert always acknowledged that Einstein was the sole author of the theory of relativity.
* Paul Dirac called it, “probably the greatest scientific discovery ever made.”

Divorce (1916-1919)

* Around the time Einstein was finalising his relativity theory his family life was deteriorating. He was worried that Maric was poisoning his boys’ minds against him. His relationship with Hans Albert was on and off.
* Einstein initially wasn’t going to get a divorce but Elsa pressured him to do so. Einstein tried bribing Maric with more money.
* Einstein developed stomach problems in 1917 and these would persist for the next four years and then linger for the rest of his life.
* Eduard was put in a sanatorium because his health was so poor.
* Einstein again offered Maric more money plus the Nobel Prize money he expected to one day win. Maric finally relented.
* Because of the war, Einstein became more and more outspoken in politics advocating internationalism, resistance to militarism, pacifism, socialism and individual freedom.
* Einstein and Maric’s divorce was finalised in December 1918.
* Einstein accepted a regular post as a guest lecturer in Zurich twice a year for a month each time, while retaining his position in Berlin. This let him spend more time with Hans Albert.
* He married Elsa in June 1919. They always had separate rooms and Elsa became very much a partner. She enjoyed being Einstein’s wife and acted much like a guardian and provider for him.

Einstein’s Universe (1916-1919)

* Around 1917, Einstein published another seminal paper, *Cosmological Considerations in the General Theory of Relativity*. The main idea; space has no borders because gravity bends back on itself. The system is closed and finite but has no edges or end.
* There was one hitch to the theory. His calculations revealed that the universe was either expanding or contracting. At the time, astronomers thought the universe was static and so he introduced the *cosmological constant.*
* In 1917, he also succeeded in deriving Planck’s blackbody quanta from Bohr’s atomic energy quanta, using statistics. This was the first time the crucial notion of probability was introduced into quantum theory.
* In 1919, Arthur Eddington sailed out with two teams to test Einstein’s predictions on the bending of light by gravity in an eclipse that was scheduled to take place that year. The results matched Einstein’s predictions almost perfectly.

Fame (1919)

* After the eclipse results Einstein’s theory of relativity burst into the popular consciousness.
* A reporter in Berlin created the story that Einstein was inspired by a man a falling from a roof (c.f. Newton’s falling apple story). Einstein wasn’t in Berlin when he conceived of this thought experiment – he was in Bern.
* Einsein had the perfect ingredients to become a star. He looked the part and could, and would, play the role.
* Relativity became associated with relativism.

The Wandering Zionist (1920-1921)

* After World War I, the rise of anti-Semitism in Germany made Einstein identify more strongly with his Jewish heritage and community. (Still nothing religious) He actually embraced the Zionist cause (although his allergy to nationalism prevented him from becoming a full-fledged member).
* In 1921, Einstein went to the US for a trip which evoked mass frenzy and press adulation. The reason was to further the Zionist cause and help build Hebrew University in Jerusalem.
* Einstein really liked Princeton.
* The mood in Germany was bad. They were looking for scapegoats for the loss of the war (for which they targeted pacifists and internationalists) and were bitter towards the French and the English. After the assassination of a well-known internationalist, police warned Einstein, he could be next.
* In 1922, Einstein joined the League of Nations International Committee on Intellectual Cooperation.
* In 1922-23, Einstein travelled for six months through Asia and Palestine to more fanfare.

Nobel Laureate (1921-1927)

* Einstein was first nominated for the Noble Prize in 1910 for special relativity but others complained that it was more about philosophy than fundamental physics. Also the Nobel Prizes are awarded for the “most important discovery or invention”.
* He was nominated several times up until 1920 and after the eclipse proved general relativity, he really should have had it. Up until then it was argued that his work was purely theoretical and lacked experimental grounding, but when he was denied it again, the reasons were more political. His superstar status and Jewish background were a couple of big reasons.
* In 1921, Einstein got fourteen official nominations, far more than anyone else, and Eddington said, “Einstein stands above his contemporaries even as Newton did.” No one won the Nobel in 1921, it was banked for the next year.
* Carl Wilhelm Oseen came to the rescue. Joining the committee in 1922, he changed tack and pushed for Einstein’s Nobel being given for the law of the photoelectric effect. Not for his theory of light quanta (what the 1905 paper was actually all about), but for the discovery of a law.
* Finally, Einstein won the Nobel Prize in 1922 (for 1921) and Bohr won it for 1922.
* In the mid-1920’s, quantum mechanics burst on the scene and earned Einstein’s dislike for two reasons. One, it only dealt in probabilities (“God does not play dice”)and two, it held that there was no objective, reality independent of an observer (“I like to think the moon is there even if I am not looking at it”).
* Einstein and Bohr (the leading quantum theorist) would spar for the rest of their lives over quantum mechanics.
* In 1924, Einstein extended a paper written by Satyendra Nath Bose and derived “Bose-Einstein statistics”. The Bose-Einstein condensation effect which came from this paper was an important discovery in quantum mechanics and it was mainly due to Einstein.
* Einstein would forever believe that quantum mechanics was incomplete.

Unified Field Theories (1923-1931)

* Einstein tried to unify gravity and the electromagnetic forces.
* Other people came up with interesting (but ultimately useless) ideas, Hermann Weyl, Theodor Kaluza, Oskar Klein and Arthur Eddington.

Turning Fifty (1929-1931)

* Helen Dukas came to work for Einstein in 1928 as his secretary.
* Einstein hired an assistant called Walther Mayer, who would become Einstein’s ‘calculator’.
* Hans Albert fell in love with a woman 9 years older than him, who Einstein did not like in the slightest, but he eventually came to accept her.
* Eduard however, was becoming dreamy and depressed as he studied psychology.
* Einstein went to America again in 1930 for two months as a research fellow at CIT, but of course he was hounded by the press everywhere he went.
* He also became quite vocal about pacifism starting the “2%” trend.

Einstein’s God

* Einstein was a determinist.
* He was definitely not an atheist.
* He didn’t believe in immortality.
* He believed in an impersonal spirit manifest in the laws of the Universe.

The Refugee (1932-1933)

* In December 1931, Einstein went to America for another two month stint at Caltech, but there were noises of something becoming permanent.
* Before he went the Woman Patriot Corporation accused him of being a militant pacifist and a communist. This prompted the FBI to start a file which would amass 1,427 pages of nonsense about him by the time he died. Einstein had to go in to the US Consular office in Berlin for a 45 minute interview which Einstein walked out of, mentioning that his countryman invited him and if he was to go as a suspect he would cancel the whole trip. He had his visa that night.
* Eventually (amidst many other continuous offers) Abraham Flexner secured him for the Institute for Advanced Study in New Jersey, next to Princeton which would open in 1934.
* Einstein left Berlin for good in December 1932.
* On January 30, 1933, Hitler took power as the new chancellor of Germany. Einstein was in Pasadena.
* Nazis ransacked Einstein’s house but Margot (Elsa’s daughter) got his papers out to the French Embassy.
* Einstein went to Belgium until the Institute would be opened.
* Einstein renounced his German citizenship and resigned from the Prussian Academy before the Nazis could strip him of both. They were furious about this.
* Curiously enough, after the Nazis issued a law that Jews could not hold any official positions, the 14 Nobel laureates and 26 of the 60 theoretical physics professors who were forced to flee, helped to ensure that the Allies developed the first atom bomb.
* Planck stayed in Germany and kept quiet, but also kept Einstein’s friendship.
* With Einstein a free agent, job offers poured in from all over Europe.
* Einstein changed his pacifism stance. His new policy was “no disarmament without security.”
* Eduard had to be committed to an asylum near Zurich. He had severe mental problems. Einstein visited him and Maric once but after this would never see either of them again.

America (1933-1939)

* Einstein arrived in America in 1933 to the usual fanfare and spectacle.
* He met President Roosevelt in 1934.
* Einstein liked the meritocracy of America and the rights extended to all individuals.
* Einstein decided to start steps to becoming a citizen in 1935. (Roosevelt actually suggested that the congress could pass a special bill on his behalf).
* He moved into 112 Mercer St.
* Elsa died in December 1936. This hit Einstein quite hard.
* Hans Albert moved to America in 1938 with his wife and two children.

Quantum Entanglement (1935)

* Einstein disliked several things about quantum mechanics. Its denial of an objective reality external and independent to humans, its inherent randomness and its violation of locality.
* He collaborated with Nathan Rosen and Boris Podolsky, to make the famous EPR paper.

The Bomb (1939-1945)

* Leo Szilard heard about the discovery of fission using uranium and realised the danger for a bomb. Him and Eugene Wigner knew that the Congo (then a colony of Belgium) had a lot of uranium and they were worried the Germans might try to buy them up. They tracked down Einstein in 1939 because they knew he was friends with the Belgium Queen.
* They decided to write to the State Department instead and the letter eventually made it to Roosevelt. When he heard it, he began the work on building the bomb which would eventually become the Manhatten Project.
* Einstein became a citizen in 1940.
* Einstein would be prevented from taking part in the project itself (he probably didn’t want to anyway) but he helped out with a couple of problems they were having.
* He later became concerned that the power of the atomic weapon might be misused. He is famous for saying, “Had I known that the Germans would not succeed in producing an atomic bomb, I never would have lifted a finger.”

One Worlder (1945-1948)

* After the atomic bomb was dropped on Japan, Einstein renewed his efforts for world federalism.
* Einstein felt that the United Nations, founded in 1945, was not good enough.
* In 1946, Einstein took on his most prominent public policy role as the chairman of the Emergency Committee of Atomic Scientists, which was dedicated to nuclear arms control and world government. He served until 1948.
* He restated his preference for democratic socialism emphasising individual freedom and personal autonomy. He was also outspoken about racial discrimination.

Landmark (1948-1953)

* Einstein’s sister, Maja, died in 1951.
* He continued to churn out papers as he searched for his ultimate unifying theory.
* The State of Israel was declared in 1948 and after the first President died in 1952, Einstein was asked to take over. He declined.

The End (1955)

* Michele Besso died only a few weeks before Einstein.
* The man himself died on April 18, 1955, at 76 with a draft for his undelivered speech for Israel Independence Day and twelve pages of mathematical equations by his bed.

Einstein’s Brain and Einstein’s Mind

* Thomas Harvey, the pathologist who performed Einstein’s autopsy took his brain without permission. When Hans Albert learnt of this, he complained but Harvey said it may be of scientific value and so Hans Albert, unsure of his legal and practical rights went along.
* Over the next forty years or so, Harvey wandered around America sending bits of Einstein’s brain to various researchers who performed various tests.
* The secret to Einstein’s creative genius was not in his brain however, but in his mind.