14 Einstein and Beyond

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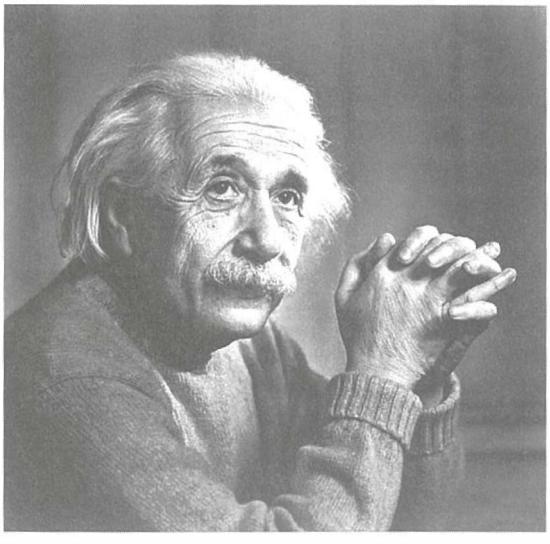
By the end of this reading, students should understand the following:

- *The need for new theories to explain certain observations*
- *The contribution of Max Planck*
- *The contributions of Albert Einstein*
- *Physical reality as described by Einstein is far removed from the way we perceive it using our senses*

Why is Einstein so important?

In 1999, the popular American *Time Magazine* asked its readership to vote for the most important person of the twentieth century. The winner was Albert Einstein.

Up till the early twentieth century Isaac Newton's laws of motion and universal gravitation could explain most natural phenomena. Indeed, in physics, it was widely believed that all breakthroughs had been made. In the scientific world, it was generally assumed that science was nearly at an end. However, new discoveries in astronomy and an increased interest in the atomic dimension produced observations that Newton's physics could not explain.



Albert Einstein 1879 - 1955

Instead of the world seeing the end of science, the world was about to enter a century in which scientists found themselves adrift in a bewildering realm of particles and antiparticles, where things pop in and out of existence in spans of time that make nanoseconds look plodding and uneventful, where everything is strange. Science was moving from a world of macrophysics, where objects could be seen and held and mesaured, to one of microphysics, where events transpire with inconceivable swiftness on scales of magnitude far below the limits of imagining. We were about to enter the quantum age.[1]

In 1900, the German physicist Max Planck, unveiled the quantum theory which posited that energy is not a continuous thing like flowing water but comes out in individualized packets, which he called quanta.

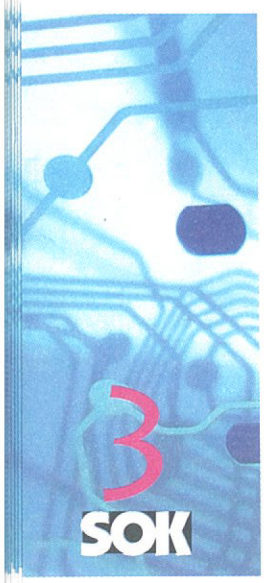
Einstein's Theories

Five years later, in the German physics journal *Annalen der Physik* appeared three papers by a young Albert Einstein, a Swiss bureaucrat working at the national patent office in Bern who had no university affiliation and was

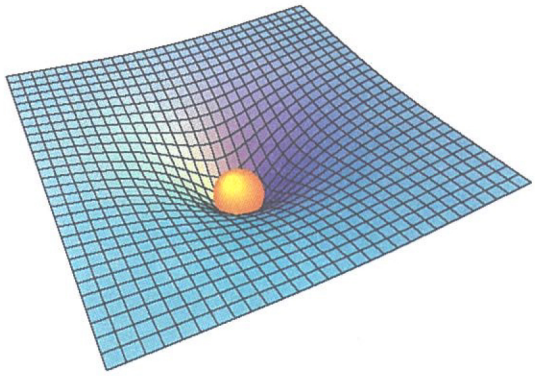
[1] B. Bryson, *A Short History of Nearly Everything* (London, 2003), 107.

completely unknown to the scientific world. These papers are often referred to as the *Annus Mirabilis Papers* (meaning the 'Year of Wonders Papers').

The first paper proposed that 'energy quanta' (now called photons), as suggested by Planck, were real, and showed that they could be used to explain such phenomena as the photoelectric effect. The second paper explained the behaviour of small particles in suspension (now known as Brownian motion) and provided empirical evidence for the existence of atoms. The last paper, published in September, entitled 'On the Electrodynamics of Moving Bodies' introduced the special theory of relativity: a theory of time, distance, mass, and energy which was consistent with electromagnetism, but omitted the force of gravity. In a brief supplement to the third paper, published in 1905, he produced his famous equation $\mathbf{E = mc^2}$, in which *E* stands for energy, *m* for mass, and *c* for the speed of light. Thanks to his first paper, in 1921, Einstein won a Nobel Prize but it was his third paper that made him famous.



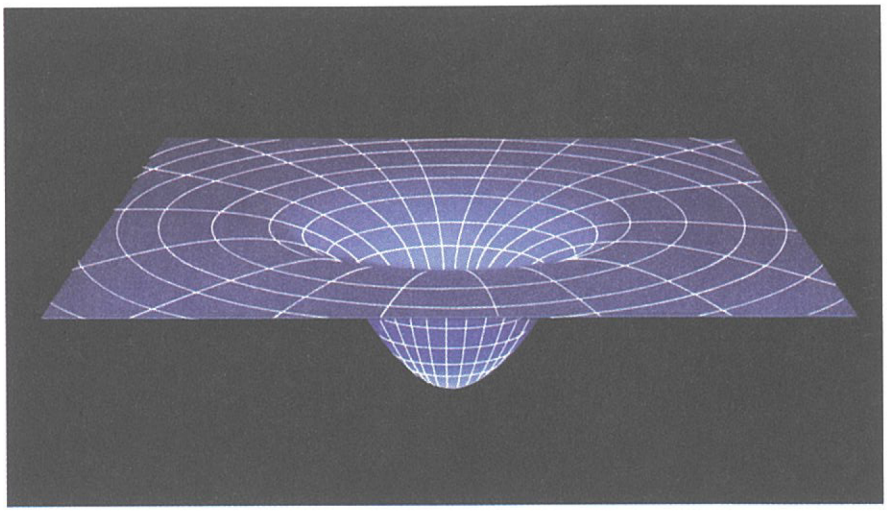
Einstein was born in Ulm, Germany in 1879, but grew up in Munich. His elementary and secondary school experiences were not happy and he was considered to be a slow learner. In 1896 he gave up his German citizenship to avoid military conscription and entered the Zurich Polytechnic Institute from where he graduated with a teaching diploma in 1900. Within a few months he started publishing scientific papers.



In 1902 Einstein obtained employment as a technical assistant examiner at the Swiss Patent office. His job was to judge the worth of inventors' patent applications for devices which required knowledge of physics. With a stable job in hand, he could marry his sweetheart Mileva, a mathematician, and this he did in 1903.

The General Theory of Relativity

One thing missing from the special theory of relativity was gravity. It only dealt with things moving in motion in an essentially unimpeded state. But what happened when a thing in motion encountered an obstacle such as gravity?[2] What happened to light when it encountered a huge mass?



The distortion of space time due to large masses

[2] In other words, 'What happens when an object is subjected to acceleration?

The 'special' theory of relativity explains that time is part of space: time is variable and ever-changing, not eternal, absolute, and immutable. Time even has shape. It is bound up with the three dimensions of space in a curious dimension known as spacetime. Bryson provides one of the most accessible explanations of this dimension:

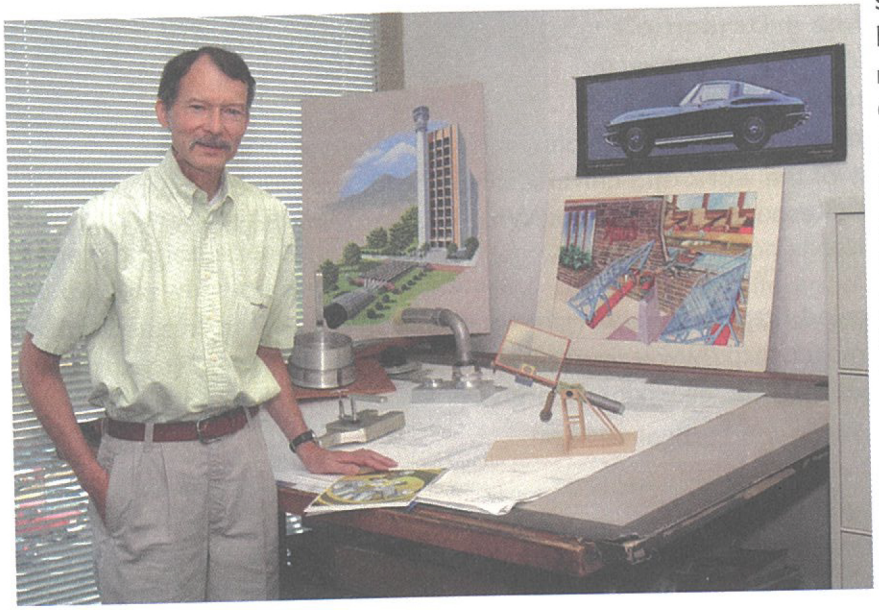
Imagine something flat but pliant (e.g. a sheet of stretch rubber) – on which is resting a heavy round object, such as an iron ball. The weight of the iron ball causes the material on which it is sitting to stretch and sag slightly. This is roughly analogous to the effect that a massive object such as the Sun (the iron ball) has on spacetime (the material): it stretches and curves and warps it. Now, if you roll a smaller ball across the sheet, it tries to go in a straight line as required by Newton's laws of motion, but as it nears the massive object and the slope of the sagging fabric, it rolls downwards, ineluctably drawn to the more massive object. This is gravity – a product of the bending of spacetime.[3]

This is the General Theory of Relativity which Einstein proposed in 1915. Through this new theory, gravity is no longer a force as Newton imagined it. Gravity does not exist in a simplistic fashion. What moves the planets and the stars is a consequence of the distortion of space and time. Now that's a difficult concept to understand! If it could be proved that light was attracted to a massive object, then Einstein's theory could be validated by an empirical observation. This was done by Arthur Eddington in 1919 who observed that, during a solar eclipse, light emanating from a star was bent by the Sun's gravity.

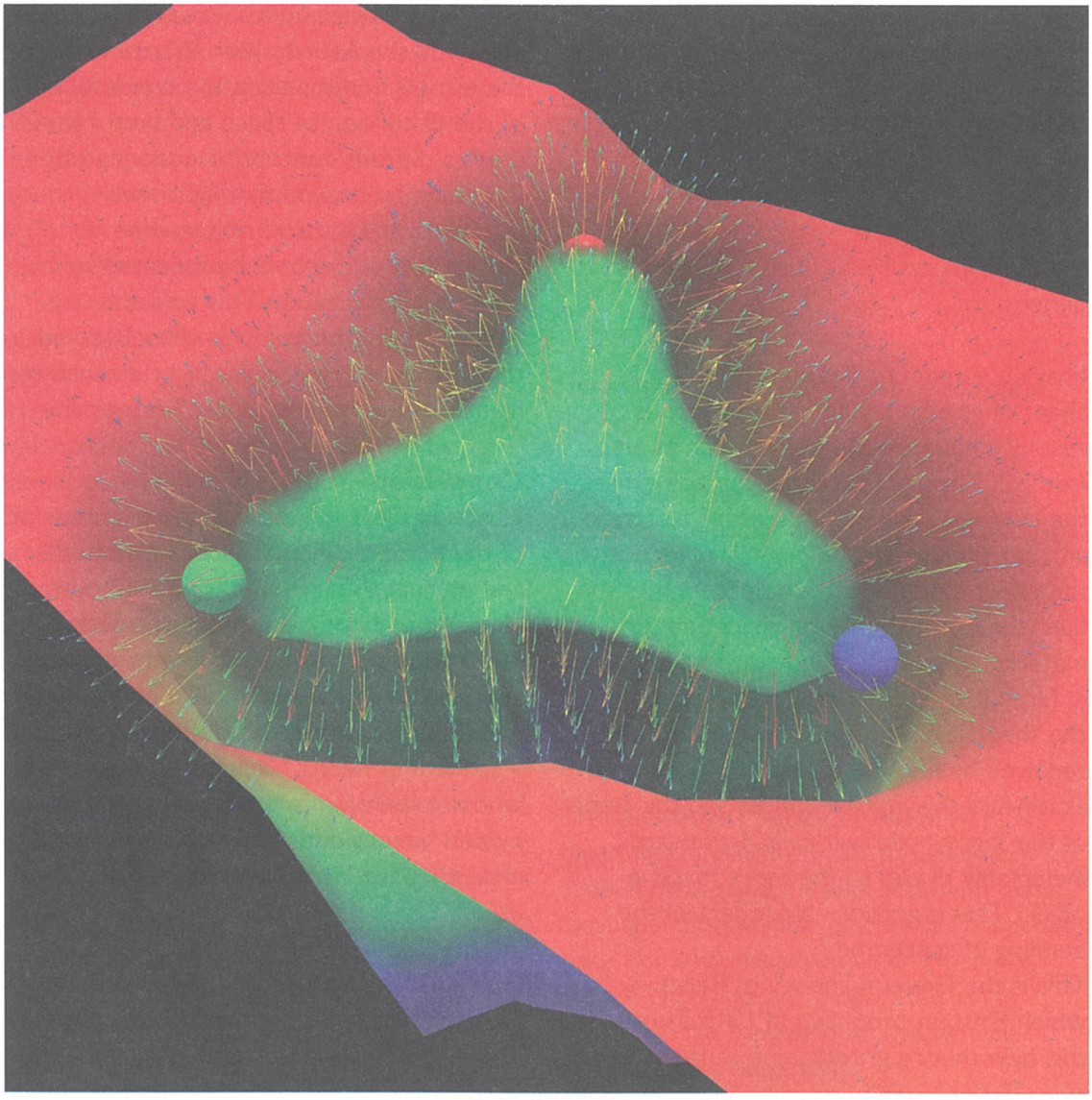
Conclusion

Einstein's ideas helped develop a new vision of the universe. Instead of being static and eternal, the universe is now an ever-changing and complex dimension. Today, a hundred years later, astronomers, physicists and mathematicians are still struggling to make sense of Einstein's outrageous legacy – spacetime warps, black holes, a universe whose expansion is accelerating, possible hidden dimensions of spacetime and other ideas that are incomprehensible to most of us.

Einstein also consolidated the idea that Newton's laws did not apply at the atomic level and helped in no small way in the study of the atom. Nevertheless he never accepted the Quantum Theory (as proposed by Nils Bohr and others), particularly because of its uncertainty principle. 'God' he said 'does not play dice.'



[3] Bryson, 113.



Gravitational Force Field formed by different celestial objects

QUESTIONS

1. What were Einstein's most important contributions to science?
2. How did our view of the world and universe change with the work of Einstein?
3. Read through the eResources listed below. What was Einstein's impact on society?

eRESOURCES

NOVA: Einstein Revealed, http://www.aip.org/history/einstein/
Einstein: Image and Impact, http://www.aip.org/history/einstein/
Einstein (from Wikipedia), http://en.wikipedia.org/wiki/Albert_Einstein

REFERENCES

B. Bryson, *A Short History of Nearly Everything* (London, 2003).
F. Golden, 'Person of the Century: Albert Einstein', available at http://www.time.com/time/time100/poc/magazine/albert_einstein5a.html