Looking back to look forward

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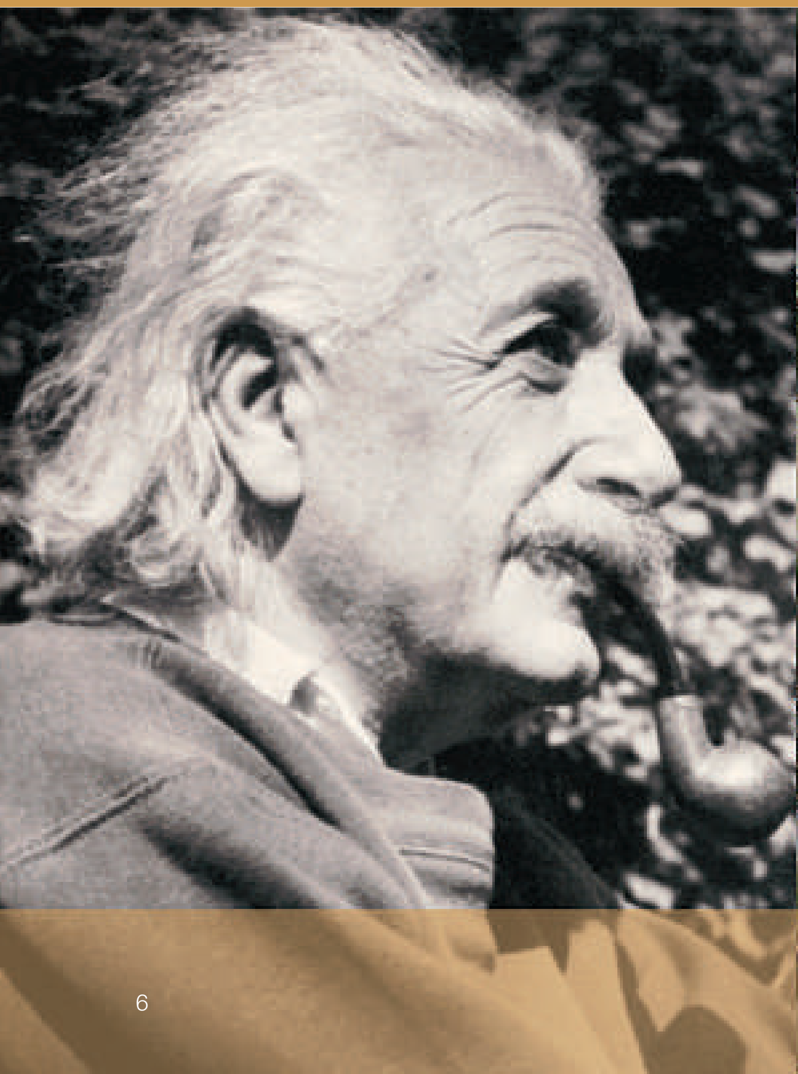
2005 is the year of physics as declared by UNESCO, and many events have been taking place around the globe to celebrate this. Past centuries have seen many outstanding physicists who have contributed to our understanding of the physical world. However, one scientific giant stands out due to his important role in changing our view of the modern world – this giant is Albert Einstein. It is no coincidence then that the year of physics coincides with the 100-year jubilee of Einstein's "wonder-year" of 1905, as well as the 50th anniversary of his death. ABB Review would therefore like to acknowledge the fundamental contribution this giant of physics provided to science.



Creator of the Relativity theory and a Nobel price winner in 1921, Albert Einstein is now considered one of the most influential physicists of all times. His theories of time and space and of gravity combined with his contributions to quantum theory have dramatically changed the way we view the world.

Einstein was born in Ulm, Germany in 1879 and died in Princeton in 1955. During his lifetime, he saw many of his theoretical works verified experimentally. In the General Theory of Relativity in 1916, he proposed that gravity is not a force but a curvature in the space-time continuum created by the presence of mass. In 1919, The Royal Society of London reported that predictions based on this theory were eventually proven by the solar eclipse that year. Now Einstein became recognized as the physicist of the century, and in 1921 he was awarded the Nobel Prize for his insight into the photoelectric process.

There is no doubt, however, that 1905 is recognized as Albert Einstein's most productive year. His ground-breaking work during this year not only transformed our understanding of quantum theory, but it also marked the transition from a more demonstrative understanding of physical processes to a reality that is described and governed by mathematical relations.

Within a seven month period, this "third class technical expert" at the patent office in Berne, Switzerland, published five theoretical papers in five different fields of physics, all of which were proven to be of fundamental importance to modern physics.

Einstein and clocks

At the beginning of the 20th Century, railways and telegraph operators were seeking a more precise synchronization of clocks across their networks. Some of these proposals landed on the desk of a young patent clerk in Berne called Albert Einstein. He pondered whether the Zytglogge clock tower (left) could genuinely be synchronized with other clocks. These musings led to the Special Relativity Theory.

In the first paper he explained the photoelectric effect by introducing photons of light. The dualism of light taking the form of both waves and particles epitomizes Einstein's trademark of being able to "think out of the box" and earned him the Nobel Prize. These theories represent the backbone of quantum physics and are fundamental for atomic and molecular physics as well as optics.

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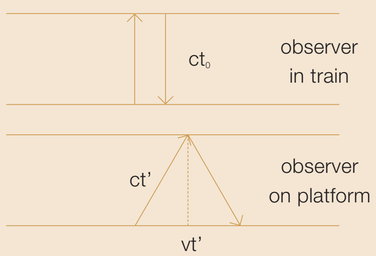
The second of Einstein's works – which was also his dissertation at the University of Zürich – dealt with the motion of large molecules, such as sugar, in a water solution. He calculated the average size of the molecule and the number in a given volume (Avogadro's number). To this day, the paper is often referenced by scientists in the fields of physics and physiology.

In his following paper Einstein developed a theory for Brownian motion. The paper dealt specifically with the random movements observed when pollen was dispersed in a water solution. Einstein's explanation was derived from the hypothesis of atoms (which at the time was heatedly debated) combined with statistical methods. His work marked the beginning of a new area of statistical physics and this theory, now known as the Fluctuation-Dissipation theory, explains the relationship between the statistical mean of microscopic and macroscopic parameters. Today these methods have permeated other fields outside physics such as share-price movement on the stock markets.

Einstein's fourth ground-breaking paper was published in 1905. Entitled "Concerning the electrodynamics of moving bodies", it establishes relativity theory and a completely new understanding of time and space. Prior to this publication, it was widely believed that time was absolute and universal, behaving identically in all reference systems. This Newtonian view that for centuries had been the foundation of physics was now being challenged by this young relatively unknown patent clerk. In 1864, Maxwell had formulated a unified theory of electromagnetism showing how electromagnetic waves propagate through space at the speed of light. From a conceptual point of view, Einstein accepted what had already appeared in Maxwell's equation, ie, the speed of light, c, is a universal constant equal for all reference systems. The consequence of this assumption, Einstein concluded, must be that time cannot be absolute but must vary relative to the observer, as the following paragraphs will try to explain.

Thought experiment 1 – *Light-path as seen by Experimenter A on board a train (upper part of* 1*) and by observer B standing on the platform (lower part* 1*):*
Experimenter A is traveling on a train which is racing through the night at a speed, v, close to the speed of light. He switches on a floor light and lets the light beam reflect vertically against the ceiling so that it returns to its original starting point. He measures the time t_0 *this round trip takes and cal-*

1 Thought experiment 1.



$t' = t_0/\sqrt{1-v^2/c^2}$
for v=c
$t_0 = 0$

culates the distance, ct_0. Observer B, who happens to be standing on the platform as the train flies by, also sees this flash of light. However, because of the moving train, his reference system assumes the light has traveled further, and therefore returns a distance vt' from its point of origin 1 *. As far as observer B is concerned, the time taken for the light to complete its journey is t' as it covers a distance of ct'. With a simple geometric calculation, t_0 and t' can be related. To reconcile this paradoxical result while accepting that c is a universal and constant factor, Einstein concluded that time in the two reference systems must appear different depending on the motion of the observer but at the same time related as shown in* 1 *.*

Based on this reasoning Einstein established a new theory of relativity for classical mechanics and introduced new concepts for space and time. Since then, much has been written about the consequences this first paradoxical theory as created by our view of the universe. Its projections have since been proven in a multitude of experiments in laboratories around the world. Its practical applications can be seen in modern satellite communications and GPS systems.

Another pillar of classical physics stipulated that mass cannot be destroyed. In many experiments, mass was carefully measured before and after a transformation, thus eluding scientists into thinking that mass was conserved. However, Einstein challenged this belief in his fifth paper of 1905. In the following example, we try to follow his thoughts on this subject.

Practical applications of Einstein's theory of relativity can be seen in modern satellite communications and GPS systems.

Thought experiment 2:

Assume a steam engine is traveling close to the speed of light. The stoker keeps feeding the fire with coal. However, the rate at which the train increases its speed is becoming smaller as it approaches the speed of light. Why is it then that as the energy input steadily increases, the speed of the train does not increase accordingly?

Einstein surmised that part of the energy input must gradually increase the mass of the train. This was one way he explained the result of the now famous relationship that spells out the energy content of a body at rest or $E = mc^2$.

With this formula Einstein unified mass and energy for the first time and showed that mass was nothing but a form of highly dense energy bundles. If mass could be converted it would provide huge amounts of energy.

This work became the basis for nuclear fission and fusion research, which has provided us with nuclear reactors for peaceful energy generation. Unfortunately, it also provided the nuclear bomb.

Einstein's curiosity was not restricted to academic and fundamental physics; he was also interested in applications that led him to a number of patents in more pragmatic areas, such as the development of an electrometer, a compass with bearings, a modern freezer, a camera, and a hearing aid.

Conclusion

Albert Einstein's scientific work has become part of the common body of physical knowledge. It has influenced many areas of physics and provided a basis for further progress.

ABB's researchers, as a matter of course, continue to use results based on Einstein's work (especially the Brownian motion).

While his contribution to physics is beyond dispute, there is another aspect of Einstein that many scientists find admirable: his passionate curiosity to know and understand nature. This drive gave him the courage to challenge the establishment to "think outside the box" and follow his intuition.

ABB scientists are encouraged to follow this way of thinking because sometimes looking back for inspiration can help us look forward with new insights.

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