Introduction

Dear Colleagues,

Albert Einstein (1879–1955) was living in Bern when – exactly 110 years ago – he turned our perceptions of space and time upside down with his theory of relativity. This world-renowned genius spent 18 years of his life in Switzerland. Of Jewish origin with Swabian roots, Einstein possessed a German, a Swiss and an Austrian passport. Later, he acquired American citizenship as well. However, he did not identify with his various nationalities but saw himself rather as a citizen of the world. He was also an ardent pacifist.

As part of the Bernisches Historisches Museum, the approximately 1000 m² of exhibition space in the Einstein Museum offer an account of the life of the physicist, interwoven with great historical events and the political and social trends of the 20th century. Some 550 original objects and replicas, 70 films and numerous animations outline the biography of the genius and his ground-breaking discoveries and, at the same time, illustrate the history of his time.

For school teachers, we offer various sources of information. As usual, you can arrange for your class to be guided through the exhibition by one of our experienced museum staff. An audio guide in nine languages is also available.

This educational material contains suggestions to help you organise your visit to the museum as well as providing information for preparatory or follow-up lessons in the classroom. The exercises for students follow the layout of the exhibition and – unless explicitly mentioned otherwise in the header – are suitable for both secondary school levels (I and II), whereby the degree of difficulty depends on the knowledge of the individual student. Whilst the main part of this educational material deals with biographical and historical facts, there is also a section on physics containing exercises which are primarily designed to help students understand the basic principles of the Theory of Relativity. Some questions are intended to be answered individually, while others can be discussed in small groups. Finally, there is a plan of the exhibition to help you find your way around the museum, plus a brief glossary of terms which may be unfamiliar to your students.

The sayings of Albert Einstein are legendary. Some of them are quoted on the task sheets to allow further reflection on the wisdom of Einstein. For example, he repeatedly expressed himself on the subject of schools and learning: “It is the supreme art of the teacher to awaken joy in creative expression and knowledge.”

On this note, we wish you and your class an interesting encounter with Albert Einstein. We look forward to your visit!

Aline Minder
Head of Education & Outreach

Ursula Schweizer
Education & Outreach Assistant
## Table of contents

Timeline Albert Einstein  
Timeline world history  

### 1 Before visiting the exhibition  
Information for teachers  
**A** Biography of Albert Einstein  
**B** Einstein as a scientist  
**C** Einstein between pacifism and the atomic bomb  

### 2 Questions about the exhibition for secondary school levels I and II  
Educational material for students  
Plan of the exhibition  
**A** Biography and world history  
  Welcome to the Einstein Museum!  
    **1** Jewish roots / Judaism at the end of the 19th century  
    **2** Ulm 1879–1880 / Albert Einstein’s family  
    **3** Munich 1880–1894 / Childhood in Munich (sec I)  
    **4** Aarau 1895 / School-leaving certificate and studies in Switzerland  
    **5** Zurich 1896–1902 / Albert Einstein becomes a Swiss citizen  
    **6** Bern 1902–1909 / Bern around 1905 (sec I)  
    **7** Berlin 1914–1933 / First World War, Weimar Republic and rise of the Nazi Party  
    **8** Princeton 1933–1945 / Einstein and the atomic bomb  
    **9** Princeton 1945–1955 / Economic boom and the post-war nuclear arms race  
  **B** Albert Einstein’s physics  
    Exercises for secondary school level II  
    **6** Bern 1902–1909 / The Special theory of Relativity 1905  
    **7** Berlin 1914–1933 / The General Theory of Relativity 1915  
  **C** Glossary  
    Information for students  

### 3 After visiting the exhibition  
Activities to help students find out more  
**A** Albert Einstein and us  
  **A** A city tour of Bern as Einstein knew it in 1900  

### 4 Solutions  

### 5 Appendix  
Literature  
List of illustrations  
Imprint  

---

Einstein Museum  Bernisches Historisches Museum  3
### Timeline Albert Einstein

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1879 Ulm</td>
<td>14 March</td>
<td>Birth of Albert Einstein into a long-established Jewish family. Father: Hermann Einstein, businessman; mother: Pauline</td>
</tr>
<tr>
<td>1880 Munich</td>
<td></td>
<td>Hermann and Jacob Einstein start up an electrical engineering company and factory</td>
</tr>
<tr>
<td>1894 Upper Italy</td>
<td></td>
<td>Living in Milan/Pavia. The factory in Munich closes down. At first, Albert continues his schooling at the gymnasium in Munich, but later he joins his parents in Milan.</td>
</tr>
<tr>
<td>1895 Aarau</td>
<td></td>
<td>Cantonal School in Aarau, school-leaving certificate</td>
</tr>
<tr>
<td>1896 Zurich</td>
<td></td>
<td>Einstein relinquishes his German citizenship</td>
</tr>
<tr>
<td>1903</td>
<td></td>
<td>1903 marriage to former fellow student Mileva Marić</td>
</tr>
<tr>
<td>1905</td>
<td></td>
<td>1905 <em>Annus mirabilis</em> (miracle year): Special Theory of Relativity, Mass-energy Equivalence Formula ($E=mc^2$), Brownian Motion, Quantum Theory of Light</td>
</tr>
<tr>
<td>1905</td>
<td></td>
<td>1905 dissertation at the University of Zurich</td>
</tr>
<tr>
<td>1907</td>
<td></td>
<td>1907 habilitation (highest academic qualification) at the University of Bern</td>
</tr>
<tr>
<td>1909 Zurich</td>
<td></td>
<td>Associate professor of theoretical physics at the University of Zurich</td>
</tr>
<tr>
<td>1911 Prague</td>
<td></td>
<td>Professor at the University of Prague; assumes Austrian nationality</td>
</tr>
<tr>
<td>1912 Zurich</td>
<td></td>
<td>1912–1914 professor at the Swiss Federal Institute of Technology (ETH) in Zurich</td>
</tr>
<tr>
<td>1914 Berlin</td>
<td></td>
<td>1914–1933 Prussian Academy of Science and University of Berlin, German citizenship</td>
</tr>
<tr>
<td>1913</td>
<td></td>
<td>Outline of the General Theory of Relativity; Theory of Gravitation</td>
</tr>
<tr>
<td>1914</td>
<td></td>
<td>Einstein also publicly reveals himself as a pacifist</td>
</tr>
<tr>
<td>1915</td>
<td></td>
<td>1915 completion of the General Theory of Relativity</td>
</tr>
<tr>
<td>1917</td>
<td></td>
<td>Introduction of the cosmological constants</td>
</tr>
<tr>
<td>1919</td>
<td></td>
<td>1919 divorce from Mileva Marić, marriage to his cousin Elsa Einstein</td>
</tr>
<tr>
<td>1921</td>
<td></td>
<td>1921 first trip to America, fund-raising for the Hebrew University of Jerusalem</td>
</tr>
<tr>
<td>1921</td>
<td></td>
<td>Nobel Prize in Physics</td>
</tr>
<tr>
<td>1933 Princeton</td>
<td></td>
<td>Emigration to Princeton, New Jersey, USA</td>
</tr>
<tr>
<td>1940</td>
<td></td>
<td>02.08.1939 Einstein urges President Roosevelt to develop a nuclear research programme</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1940 acquires American nationality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>but also retains his Swiss citizenship</td>
</tr>
<tr>
<td>1952 Princeton</td>
<td></td>
<td>1952 Israel invites Einstein to become President of Israel, but he declines.</td>
</tr>
<tr>
<td>1955 Princeton</td>
<td></td>
<td>18 April, Einstein dies of aortic rupture</td>
</tr>
<tr>
<td>Year</td>
<td>Event</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>1917</td>
<td>Russian Revolution</td>
<td></td>
</tr>
<tr>
<td>1918/19</td>
<td>November Revolution in Germany</td>
<td></td>
</tr>
<tr>
<td>1919</td>
<td>Founding of the Weimar Republic</td>
<td></td>
</tr>
<tr>
<td>1919/20</td>
<td>Peace Treaty of Versailles</td>
<td></td>
</tr>
<tr>
<td>1929</td>
<td>29 October, Wall Street Crash, world economic crisis</td>
<td></td>
</tr>
<tr>
<td>1933</td>
<td>30 January, Adolf Hitler becomes Chancellor of Germany, end of the Weimar Republic</td>
<td></td>
</tr>
<tr>
<td>1939–1945</td>
<td>Second World War</td>
<td></td>
</tr>
<tr>
<td>1945–1949</td>
<td>Germany is occupied</td>
<td></td>
</tr>
<tr>
<td>from 1945</td>
<td>East-West conflict, division of Europe: “Cold War” between the US and the Soviet Union, decolonisation, nuclear armament, reparation payments</td>
<td></td>
</tr>
<tr>
<td>1947</td>
<td>India becomes independent</td>
<td></td>
</tr>
<tr>
<td>1948</td>
<td>Founding of the State of Israel</td>
<td></td>
</tr>
<tr>
<td>1949</td>
<td>Division of Germany into the Federal Republic of Germany (West Germany) and the German Democratic Republic (East Germany)</td>
<td></td>
</tr>
<tr>
<td>1950–1953</td>
<td>Korean War</td>
<td></td>
</tr>
<tr>
<td>1955</td>
<td>Warsaw Pact</td>
<td></td>
</tr>
<tr>
<td>Rearmament of Germany</td>
<td></td>
<td></td>
</tr>
<tr>
<td>from 1957</td>
<td>Unification of Europe</td>
<td></td>
</tr>
<tr>
<td>1961</td>
<td>Building of the Berlin Wall as part of the East German border</td>
<td></td>
</tr>
<tr>
<td>1962</td>
<td>Cuba Missile crisis, nuclear threat</td>
<td></td>
</tr>
<tr>
<td>1964–1975</td>
<td>Vietnam War, proxy war between the US and the Soviet Union</td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td>The US achieve the first moon landing</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>9 November, fall of the Berlin Wall, “Wende” (turning point) in Eastern Europe</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>German reunification</td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>Collapse of the Soviet Union, end of the Cold War</td>
<td></td>
</tr>
</tbody>
</table>
Before visiting the exhibition
Information for teachers

A Biography of Albert Einstein ............................................. 7
B Einstein as a scientist ..................................................... 11
C Einstein between pacifism and the atomic bomb ............. 14
Childhood in Munich

Albert Einstein was born in Ulm on 14 March 1879. His father was a businessman who ran a bed feather business. Only a year after Albert’s birth, the family moved to Munich. Einstein’s mother Pauline came from a well-to-do family and she was considered educated, caring and musical. She passed on her love of music to her son Albert and he was taught to play the violin from the age of six. Although Einstein’s parents were Jewish, they did not practise their religion.

From June 1880 the family lived in Munich, where Einstein’s father Hermann and his brother Jacob managed their own company, which manufactured gas and water installations as well as electric power plants. In 1881 Albert’s sister Maria (called Maja) was born. She and her brother remained close throughout their life and, after the Second World War broke out, Maja followed her brother to Princeton, where she died in 1951.

From an early age, Albert Einstein showed aversion to all forms of violence and took exception to Prussian military school drill – even though, according to his mother's letters, he was top of the class. Albert received a number of books from his relatives and from friends such as Max Talmud (a medical student who often ate lunch at the Einsteins’), and these awakened his curiosity about natural science. When he was only 13, he realised there was a discrepancy between natural science and religion. At the end of 1894 he prematurely left his school in Munich and followed his parents to Milan and Pavia, where they had moved following the liquidation of their enterprise “Einstein & Cie.”

Later on, he obtained his school-leaving certificate at the Cantonal School in Aarau, afterwards studying at the Polytechnic (today the ETH) in Zurich. A few weeks before his seventeenth birthday, he relinquished his citizenship of the Kingdom of Württemberg (at that time part of the German Reich) to avoid being called up for German military service.

As a student in Zurich

Albert Einstein studied to become a teacher of mathematics and science at the Zurich Polytechnic from 1896 until 1900. During this time, he met his first wife, Mileva Marić, from Serbia. She was the only female student in his year and the only other student majoring in physics. To improve his chances of finding a job, he saved up to apply for Swiss citizenship, which he received on 21.02.1901. After completing his studies, he took temporary jobs as an assistant teacher in Winterthur and Schaffhausen until, in 1902, he was employed by the Federal Patent Office in Bern.

His girlfriend Mileva Marić twice failed the qualifying examination. In 1901 she became pregnant by Einstein. At that time, an illegitimate child was a social taboo. It would have cost Albert his career and Mileva, as well as her child, would have become social outcasts. So the illegitimate daughter, who was called

An anecdote from his pre-school days

At the age of 67, Albert Einstein looks back on the following experience: “A pivotal experience (...) occurred when I was 4 or 5 years old: my father showed me a compass. To me, the way this needle moved without even being touched was evidence that there was more to our world than meets the eye (...). I can still remember (...) that this experience had a profound and lasting effect on me. There had to be something behind things, hidden deep down.”

Anecdotes from Einstein’s student days

“I followed some of the lectures with much interest. Otherwise, I often played truant and avidly studied the masters of theoretical physics at home”, Einstein wrote in a letter to Mileva Marić. Because he often failed to attend the “Practical beginners’ course in physics” Einstein received a reprimand for “lack of diligence” and the lowest possible mark (1). His professor is said to have asked him “Why don’t you study medicine, law or philology instead?” Einstein replied: “Because I have even less talent for those subjects. So why shouldn’t I at least have a go at physics?”
“Lieserl”, was born in Mileva’s hometown Novi Sad (then in Austria-Hungary) in 1902. The intention was for her to be brought up by Mileva’s family, but after 1903 all trace of the child is lost.

Anecdote from the military recruitment
Einstein became a Swiss citizen in 1901 and was immediately called to the district military command in Zurich for a medical to determine whether he was fit for military service. He was never called up on account of his varicose veins, flat feet and foot perspiration, but he had to pay military service exemption tax until his 42nd birthday.

At the Patent Office in Bern
On 22 June 1902, Einstein became a third-class technical specialist at the Federal Patent Office in Bern with an annual salary of 3500 Swiss francs. This permanent employment enabled him to marry Mileva Marić on 6 January 1903. His son Hans Albert was born in 1904, followed by his second son Eduard in 1910.

The job at the Patent Office was a godsend to Einstein. He reported to a friend that he “worked 8 hours a day, 6 days a week, whilst giving private lessons and doing scientific work on the side.” In other words, he had sufficient time after work to pursue his theories and ideas, debate with his friends of the “Olympian Academy” and at the same time continue his autodidactic studies. The “Olympian Academy”, as it was facetiously named by its members Albert Einstein, mathematics student Conrad Habicht and philosophy student Maurice Solovine, was a debating and discussion group. The three men met regularly for sausages, cheese and tea, and to discuss the scientific and philosophical works on their pre-arranged reading list.

It was during this productive period that Einstein wrote some of his most important works and the year 1905 became known as Einstein’s Miracle Year (Annus Mirabilis). He published five articles in the scientific journal “Annalen der Physik” (Berlin) which revolutionised the natural sciences:

1. Theory of Photoelectric Effect (Quantum Theory of Light)
2. Brownian Motion (identification of Brownian particles as molecules and atoms)
3. Molecular Dimensions (description of Brownian Motion provides the molecular dimension)
4. Special Theory of Relativity
5. Mass-energy Equivalence Formula $E = mc^2$, elaboration of the Special Theory of Relativity

Einstein’s scientific work is presented in detail from page 11.

In 1908, Albert Einstein received the habilitation from the University of Bern. The following year, he left the Patent Office.

Zurich – Prague – Zurich – Berlin
In 1909, Einstein became an associate professor of physics at the University of Zurich and in 1911 he took up a post as professor at the German University of Prague. As a scientist, Einstein felt isolated in Prague and he does not seem to have settled down there otherwise.

In the meantime, Einstein’s works had attracted international attention, which enabled him to return to the Institute of Technology in Zurich (formerly the Polytechnic) in 1912, where he became professor of theoretical physics.

After the Prussian Academy of Sciences had accepted Albert Einstein as a full member, he went to Berlin in 1914. In 1917 he became director of the newly founded Kaiser-Wilhelm Physics Institute, where he received a fixed annual salary and was exempted from all teaching duties.

While he was in Berlin, an earlier affair with his cousin Elsa was rekindled and, after only three months there, Mileva sadly returned to Switzerland. The couple were divorced in 1919 and Einstein undertook to let his family have not only half his salary but also the full amount of the expected Nobel Prize money.

In 1919, the General Theory of Relativity was proved – Albert Einstein postulated the equivalence of acceleration and free fall – and he became world-famous.
The same year, he married Elsa Löwenthal, who already had two daughters, Ilse and Margot.

Since 1908, Albert Einstein had already been nominated several times for the Nobel Prize, but for many years one of the members of the Nobel Committee had challenged the theory of relativity. However, since prestigious Nobel prize-winners had repeatedly supported the nomination of Albert Einstein, he eventually received the Nobel Prize in Physics on 9 December 1922, backdated to the year 1921. It should be mentioned that the prize was not awarded for his Theory of Relativity, but for the Theory of Photoelectric Effect.

Having suffered health problems and exhaustion, Albert Einstein purchased a summer residence in Caputh, near Potsdam. Against a background of increasing political radicalisation and open hostility, Caputh was a welcome retreat for him. Some wealthy friends gave the enthusiastic sailor—who, by the way, could not swim—a boat called “Tümmler”.

When Adolf Hitler came to power in 1933, Einstein happened to be in Pasadena (USA). His apartment at Haberlandstrasse 5 in Berlin, the summer residence in Caputh and his boat were seized by the Prussian state, his bank accounts were frozen and his assets confiscated.

Exile in Princeton

In July 1921, Adolf Hitler became leader of the National Socialist German Worker’s Party. In his book “Mein Kampf” he expounded his anti-Semitic and racist ideology. Faced with a political crisis, the German President Paul von Hindenburg appointed Hitler as Chancellor on 30 January 1933. No sooner had Hitler come to power than he began to impose the laws of “Gleichschaltung” (enforced political conformity) as well as banning a great number of organisations and political parties, and issuing emergency regulations. In this way, he managed to bypass the constitution. New laws and pogroms ostracised German Jews and deprived them of their rights. Not only Jews, but Sinti and Roma, homosexuals, mentally handicapped persons, political opponents, rivals from the party’s own ranks and so-called social misfits were imprisoned, tortured and murdered in labour and extermination camps (concentration camps). Today, it is estimated that this genocide resulted in the death of approximately 6 million people.

Following Hindenburg’s death on 2 August 1934, Adolf Hitler also assumed the office of President of the German Reich.

Despite being an international celebrity, Albert Einstein found life increasingly difficult, due to his Jewish origin, after the National Socialists seized power. His
name featured on a hit list with a bounty of 5000 dollars on his head. Moreover, a German magazine put him on a list of “Enemies of the German nation” with the remark “not yet hanged.”

After the seizure of power by the National Socialists in 1933, Einstein decided never to return to Germany. He resigned from the Prussian Academy of Science and handed back his German passport. His application for expatriation was refused. Instead he was punished by being forcibly deprived of his citizenship. After this, the Institute for Advanced Study in Princeton (New Jersey) under Abraham Flexner arranged for his emigration to the US.

During Einstein’s time in Princeton, physics had started to develop in ways that deviated more and more from his own ideas. Quantum allows the calculation of the physical properties of matter in the field of nuclear and particle physics, atomic physics and solid-body physics. Quantum mechanics can also be applied to chemical systems. One of the core tenets of quantum mechanics is that it is not possible to determine exactly the whereabouts and speed of an elementary particle and that a certain amount of randomness is involved (Heisenberg’s Uncertainty Principle, 1927). Einstein doubted this new conception - hence his remark that “God does not play dice” - and proceeded to work alone on a unified field theory. However, this turned out to be a dead end.

Various other works were produced, which were fed into research and which, for researchers, paved the way to the Nobel Prize. For example in 1924, Einstein and the Indian physicist Satyendranath Bose described the Bose-Einstein condensate, an extreme state of matter achieved at very low temperatures. In 2001, several researchers received the Nobel Prize in Physics for their experimental preparation of such condensates.

After the death of the first Israeli president Chaim Weizmann, Albert Einstein was invited to succeed him in 1952. Although the offer moved him deeply, he declined it, saying that he was a scientist, not a politician.

Albert Einstein died in Princeton at the age of 76 on 18 April 1955 from a rupture of the aorta. He had been suffering from aortic aneurysm since 1948.

In his will dated 18 March 1950 he left all his writings to the Hebrew University in Jerusalem. The university subsequently incorporated the material in the Albert Einstein Archive. He left money to his family as well as to his secretary Helen Dukas.

**Anecdote about Einstein’s brain**

While carrying out an autopsy on 18 April 1955, Einstein’s doctor, Thomas Harvey, removed the brain – without the family’s consent. He had assumed that the brain of such an important scientist must be larger and heavier than that of an average person (1200–1500 grams). However, at 1230 grams, the weight of Einstein’s brain was rather modest. So Harvey made thin sections for examination under the microscope, which he pigmented and photographed. He then sent the photographs to a few carefully selected colleagues. Harvey was dismissed, lost his licence to practise medicine and in subsequent years was forced to earn a living as a factory worker and harvester. He kept the rest of Einstein’s brain at his house for many years. In accordance with Einstein’s wishes, his family had his body cremated and the ashes were scattered at an unknown location.
"I think that only daring speculation can lead us further, not the accumulation of facts."

Already as a teenager, Einstein carried out experiments to elucidate the laws of nature. During his tenure at the Federal Patent Office in Bern, he developed his “little machine”, a device for measuring small voltage differences; in Berlin, he conducted experiments on magnetisation. Until his death he possessed, always together with another scientist, over 20 patents. For example, a patent for a coolant pump which is still used today for nuclear reactors, or a gyrocompass, an automatic camera and a hearing aid.

He published numerous articles and books on his work. Some of his theories formed the basis of modern physics, as opposed to classical physics with its absolute conceptions of space which had been handed down from the previous century, as represented by people like Isaac Newton.

The fact that his physical theories, speculations and ideas of relative space and time have had a considerable impact on our own everyday life underlines the importance of research in theoretical physics.

The so-called “miracle year” 1905 is considered a turning point in his academic career, and for his career as a scientist. As a 26-year-old, he published the following five works which brought him international acclaim.

1. The quantum theory of light – “On the production and transformation of light from a heuristic point of view”

Albert Einstein was awarded the 1921 Nobel Prize for this work. Einstein expanded Max Planck’s theory of thermal radiation (1900) to the hypothesis of real light quanta. He assumed that light consists of a finite number of light quanta in wave packets.

Light is made up of individual particles (photons) which, through impact, transfer all their energy onto semiconductor metal plates and release their electrons. The photon energy must be at least equal to the binding energy. The energy of the released electron is then dependent on the frequency of the incident light. At higher light intensities a higher number of photons hit the metal, releasing more electrons.

The previous wave theory of light was not wrong, but it could lead to contradictions with experiments, especially when applied to the generation and transformation of light. However, it functions perfectly in optical phenomena such as the refraction or diffraction of light. Einstein’s quantum theory of light drew attention to the duality of waves and particles. One of the main applications of the light quantum hypothesis is stimulated emission: if you send a light particle with an excess of energy towards a large quantity of atoms, all these atoms will be stimulated. Further photons will then cause the stimulated atoms to send out a number of coherent (“chained”) light particles. Without this phenomenon there would be no laser. A laser beam can focus single-colour light in this manner.

Practical relevance: Today, this theory is applied wherever light is converted into electricity, for example, in a digital camera or a solar system. It can be found in every CD player and scanner, and medical devices have come to depend on the laser beam.

2. The true size of the atom – “A new determination of molecular dimension”

Einstein was awarded a doctorate in physics for his dissertation in 1906.

On the basis of data on sugar solutions of known concentration and a new formula for their diffusion, Einstein showed how we can estimate the molecular size and the Avogadro constant (number of molecules in a mole) from the viscosity of a liquid. For Einstein, this was a breakthrough in his efforts to prove the existence of atoms which, at that time, was still hotly contested.

Practical relevance: Practical applications can be found in aerosol research (dispersal of the smallest drops of liquid), in the examination of the behaviour of casein particles in milk when making cheese, and in the petrochemical (plastics) or building industries. The theory provides a logical link between gas and solids and explains many processes where currents in liquids play an important role (such as in chemistry and medicine), which otherwise would have remained incomprehensible.

Anecdote about his dissertation

Einstein smiled as he told his biographer Carl Seelig that the University of Zurich initially returned his thesis with the remark that it was too short. He said that “After he had inserted just one more sentence, the work was accepted without protest.”
3. The Brownian thermal motion theory – “About the movement of suspended particles in a stationary liquid according to the molecular kinetic theory of heat”

Confirmation of the molecular structure of matter by describing the “Brownian thermal motion” theory formed the basis of modern statistical mechanics.

The random movement of particles (pollen suspended in water) had already been observed through a microscope by Robert Brown in 1827. Based on Brown’s findings, Einstein assumed that the movement of molecules dissolved in liquid is due to the thermal motion of the molecules.

In his theory of “Brownian thermal motion” Einstein provided direct and conclusive evidence of the molecular structure of matter on a purely classical basis. This proved beyond doubt the existence of the molecules and atoms that make up these particles.


In this treatise he expounded his Special Theory of Relativity using an analysis of time and space: time and space are variable, while the speed of light is constant.

While observing time and space, Einstein based his assumptions on the principle of relativity and the constancy of the speed of light. As a constant, it rendered the controversial “ether” as a transport medium for light superfluous.

This assumption also contradicted the Newtonian notions of space, according to which time passes as an absolute – from moment to moment - and thus light does not exist as a constant. But Einstein remained undeterred.

To the observer, an object that passes at high speed appears strangely shortened and distorted. In a moving system, time also passes more slowly for outside observers. That means clocks which are moved go more slowly; units of movement are shorter in the direction of movement.

Einstein realized that it was time and space that changed. They are connected by their reference value, the speed of light to time/space.

Since the Special Theory of Relativity relates to uniformly moving systems, Einstein sought a further development of his formula, which should also apply to accelerated and slowed-down bodies.

Einstein’s insight changed the way in which we think about time and space by linking them together. Events that seem simultaneous to one observer may seem to happen at different times to another observer moving relative to the first.

Practical relevance: GPS (Global Positioning System)

Every satellite positioning system on the ground employs Einstein’s Special and General Relativity theories. Compared with the clocks on our planet, atomic clocks on board GPS satellites that orbit the earth lose about 7 microseconds per day due to their speed (about 14,000 kilometres per hour). On the other hand, atomic clocks at an altitude of about 20,000 kilometres are subjected to the gravitational forces of Earth far less than clocks on the ground. Thus, clocks in the satellites run faster than those on Earth and gain 45 microseconds per day. The difference of 38 microseconds per day, converted into distance, would cause a GPS system that does not take into account the effects of relativity to show an error of 11 kilometres per day. In addition, the satellites move in an orbit where their distance from the surface of the earth and their speed is not always constant.

5. E = mc² – “Does the inertia of a body depend on its energy content?”

The world-famous equation is a three-page addendum to the Special Theory of Relativity, which confirms the natural law of mass-energy equivalence. If an object does not move, it has no kinetic energy and it follows that energy equals mass multiplied by the speed of light squared.

By applying the Special Theory of Relativity Einstein derives the energy formula \( E = mc^2 \).

The energy emitted by a body of electromagnetic radiation reduces its mass by a factor of \( E/c^2 \). The mass \( m \) of a body is a measure of its energy content \( E \). Since \( c \) (speed of light) is relatively great, the energy contained in each piece of matter must be incredibly large.

Practical relevance: the generation of nuclear power is one practical demonstration that mass and energy are essentially the same. In a nuclear power plant atomic nuclei are split in a controlled nuclear reactor - as many of them as you need for energy production.

In \textbf{nuclear fission} a nucleus can be split into two or more fragments. Elementary particles are released, in
particular neutrons. A nuclear fission can be triggered by bombardment with nuclear particles. Atomic nuclei such as uranium-235 or plutonium-239 can be bombarded with relatively slow neutrons. The energy is transferred to the surrounding material. Collision of the atoms causes heating. Uranium nuclei split into fragments during nuclear fission and, in addition, neutrons are released. These neutrons in turn cause the splitting of other uranium nuclei. Such a chain reaction is the basis for a nuclear reaction, but it must be well supervised. Heat from nuclear fission is used for the generation of nuclear energy. The chain is controlled and stopped by the fuel rods. This is different to the atomic bomb, where the chain reaction is uncontrolled, creating an enormous destructive energy burst.

In 1907, Einstein started research on the General Theory of Relativity, which was first formulated in full in 1915 – in the middle of the First World War. General relativity deals with the fundamental equality of all spatio-temporal coordinate systems on the basis of equivalence of inertial and gravitational mass.

In contrast to special relativity, general relativity indicates gravity as a geometric property of a curved four-dimensional time-space. Matter, such a star, bends space and affects time. Conversely, a curved time-space affects the motion of matter. The movement can take place only along the curved space.

After successful verification of the minimal, almost immeasurable deflection of light by the British solar eclipse expeditions in Brazil and near the West African coast in May 1919, Einstein again received international acclaim.

Caption: Example of a neutron-induced fission of uranium-235 (MeV = Mega electron volts)
“I had no choice” but to speak out after the atomic bombing of Hiroshima and Nagasaki, “although I have always been an ardent pacifist”, wrote Einstein three years before his death. “To my mind, to kill in war is not a whit better than to commit ordinary murder.”

Albert Einstein had already showed signs of being a pacifist in his youth. While still a schoolboy in Aarau, he relinquished his German citizenship to avoid being called up for German military service. Since Swiss democracy was the political system that appealed to him most, he took Swiss citizenship a few years later. Although he generally approved of the Swiss system of government, he criticised Switzerland’s treatment of refugees during the Second World War.

After the First World War, Einstein was relieved when the Weimar Republic (parliamentary republic, 9 November 1918 until 30 January 1933) was established. Germany had become a democracy – but not for long.

Einstein constantly expressed his political opinions and publicly opposed the idea of war. After the First World War he feared that the peace conditions of the Treaty of Versailles might lead to the outbreak of a new war – an appraisal of the situation that turned out to be correct.

As a conscientious objector he considered that “The best way of overcoming militarism, which is the curse of our times, is to refuse military service.” Later, Einstein turned away from this radical form of pacifism because he realised that a forceful aggressor such as Nazi Germany posed a grave threat to all mankind:

“When Fascism raised its ugly head, I realised that this pacifist stance could no longer be defended, otherwise the whole world would fall into the hands of mankind’s worst enemies. The only way to defeat organised force is through organised force.”

On 2 August 1939 Einstein wrote to the American President Franklin D. Roosevelt, warning him that, as Nazi Germany had successfully split the atom, that country might be on the point of constructing an atomic bomb. He asked the president to launch America’s own nuclear research project. In 1942 an American research programme for the construction of an atomic bomb - the “Manhattan Project” - was launched with an overall budget of two billion US dollars. The research was based on Einstein’s equation \( E= mc^2 \), according to which an unbelievable amount of energy can be generated from a small body. For example, splitting 1 gram of uranium-235 will release as much energy as is needed to burn 2.4 tons of coal.

Einstein did not take part in the “Manhattan Project”. In view of his openly expressed sympathy for Communism, his anti-military stance and his encouragement of conscientious objectors, the FBI considered him to be a security risk. In fact, they had been watching Einstein ever since his arrival in the US and their file on him contained over 2000 pages.

The nuclear weapons developed under the “Manhattan Project” led to one of greatest human tragedies of all time in Japan. In the aftermath of the disaster, Einstein gave an interview to Newsweek in 1947. He said he would never have written to Roosevelt asking him to engage in nuclear research if he had known just how little-advanced the German atomic bomb projects had really been. But he added that this development would still have taken place without his involvement.

He had tried to warn President Roosevelt against using the bomb. However, Roosevelt died suddenly and his successor Harry S. Truman was determined to demonstrate the strength of the US. Three months after Hitler’s suicide and the unconditional surrender of Germany, the Japanese cities Hiroshima and Nagasaki were destroyed by atomic bombs. After the disaster, Julius Robert Oppenheimer, the scientist in charge of the “Manhattan Project”, said: “In a crude sense, the physicists have come to know sin, and this is a knowledge which they cannot lose.”
Albert Einstein was shocked at the extent of the devastation. Thereafter, he supported nuclear disarmament. Shortly before his death, he signed the Russell-Einstein Manifesto, which contains the following resolution:

“In view of the fact that in any future world war nuclear weapons will certainly be employed, and that such weapons threaten the continued existence of mankind, we urge the governments of the world to realise, and to acknowledge publicly, that their purpose cannot be furthered by a world war, and we urge them, consequently, to find peaceful means for the settlement of all matters of dispute between them.”

Explosion of the first atomic bomb “Trinity”, code name “The Gadget”.
# Exercises for secondary school levels I and II

Documentation for students

Plan of the exhibition  

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
</table>
| **A** | Biography and world history  
| | Welcome to the Einstein Museum! |
| 1 | Jewish roots / Judaism at the end of the 19th century |
| 2 | Ulm 1879–1880 / Albert Einstein’s family |
| 3 | Munich 1880–1894 / Childhood in Munich (sec I) |
| 4 | Aarau 1895 / School-leaving certificate and studies in Switzerland |
| 5 | Zurich 1896–1902 / Albert Einstein becomes a Swiss citizen |
| 6 | Bern 1902–1909 (sec I) / Bern around 1905 |
| 7 | Berlin 1914–1933 / First World War, Weimar Republic and rise of the Nazi Party |
| 8 | Princeton 1933–1945 / Einstein and the atomic bomb |
| 9 | Princeton 1945–1955 / Economic boom and the post-war nuclear arms race |
| **B** | Albert Einstein’s physics  
| | Exercises for secondary school level II |
| 6 | Bern 1902–1909 / The Special theory of Relativity 1905 |
| 7 | Berlin 1914–1933 / The General Theory of Relativity 1915 |
| **C** | Glossary  
| | Information for students |
Plan of the exhibition

SECOND FLOOR
BERNISCHES HISTORISCHES
MUSEUM

1. Jewish Heritage
1880–1894

2. Ulm
1879–1880

3. Munich
1880–1894

4. Aarau 1895

5. Zurich
1896–1902

6. Bern
1902–1909

7. Berlin
1914–1933

8. Princeton
1933–1945

9. Princeton
1945–1955

Special Theory of Relativity

General Theory of Relativity

Cosmology

Mirrored staircase

5. Zurich
1896–1902

4. Aarau 1895

6. Bern
1902–1909

7. Berlin
1914–1933

8. Princeton
1933–1945

9. Princeton
1945–1955

1. Jewish Heritage
1880–1894

2. Ulm
1879–1880

3. Munich
1880–1894

4. Aarau 1895

5. Zurich
1896–1902

6. Bern
1902–1909

7. Berlin
1914–1933

8. Princeton
1933–1945

9. Princeton
1945–1955

Special Theory of Relativity

General Theory of Relativity

Cosmology

Mirrored staircase
Welcome to the Einstein Museum!
Albert Einstein spent 18 years of his life in Switzerland – seven of them in Bern, which is where his two sons were born. It was also in Bern, during his so-called “Miracle Year” 1905, that he developed pioneering theories such as the Special Theory of Relativity and the energy equation E=mc². These task sheets will show you the different phases of the life of this exceptional scientist, provide an insight into the principal events of the 20th century and explain the most important results of Einstein’s scientific theories.

On page 17 you will find a plan of the exhibition. The task sheets are arranged chronologically and correspond to the names of the exhibition rooms. You may find expressions which are unfamiliar to you, either in the exhibition or on the task sheets. The glossary on page 40 is there to help you. Please use an (online) encyclopaedia for further research or ask your teacher if there is anything you do not understand.

Let’s go!

Who’s who? During your visit to the exhibition you will come face-to-face with members of Albert Einstein’s family. Write each name next to the appropriate portrait.

- Father Hermann
Judaism at the end of the 19th century

Ever since the Romans occupied Judea in 63 BC, Jewish people have been politically disadvantaged, oppressed and persecuted. The theme of the first part of the exhibition is Albert Einstein’s Jewish origin. His ancestors were long-established Jews who had been living in Swabia at least since the 17th century.

In which ways could Jews practise their faith during the 19th century?

- 
- 
- 

What path did the Einsteins choose? Tick the correct answers.

- Orthodoxy
- Strictness
- Marrying outside their religion
- Supporting the Jewish National Fund
- Zionism
- Integration
- Returning to their roots
- Commitment to a state of their own for the Jews
- Sidelocks
- Phylacteries
- Kippahs
- Eating kosher food
- Wearing modern or fashionable clothing
- Attending state schools
- Reading the Talmud

“It was only in the Prussian society of the German Reich that I discovered that I was Jewish – a discovery I made thanks to the Gentiles rather than the Jews.”
Albert Einstein’s family

Einstein received a solid middle-class education. It is said that on his fifth birthday his father gave him a compass and his mother gave him a violin. His mother Pauline passed on her love of music to her son while he was still very young and Albert took violin lessons – albeit somewhat reluctantly.

Which of these statements about the Einstein family is correct?
Tick the correct answers.

☐ His parents supervised his homework every day.
☐ Albert Einstein attended Catholic religious instruction at school and Jewish religious instruction from a private teacher.
☐ As a child, Einstein was an avid reader.
☐ Young Albert was such a poor student that he received private tuition.
☐ The Einsteins ran a beer tent at the Oktoberfest.
☐ Einstein’s parents regularly attended synagogue.
☐ Einstein’s mother Pauline was well educated, played the piano and was wealthy.
☐ His father Hermann read the Torah every day.
☐ Einstein remained close to his brother Hans throughout his life.
☐ Einstein received excellent school reports.
☐ The Einsteins did not cook kosher food.
☐ The other children called Einstein “Brother Bore” and “Biedermann” (“Petty Bourgeois”).
☐ Albert Einstein wanted to become a soldier.

“… as to Schubert, I have only this to say: play the music, love – and shut your mouth!”
Childhood in Munich

In the exhibition there is a showcase containing toys and objects used for leisure activities.

What did young Albert do in his spare time?
Circle the correct answers.
School-leaving certificate and studies in Switzerland
Einstein received his schooling at the gymnasium in Munich and the Cantonal School in Aarau. Afterwards, he studied at the Polytechnic in Zurich and graduated with a teaching diploma in mathematics and physics. At first he worked as an official at the Patent Office in Bern because he was not able to pursue an academic career immediately.

Compare the photo of Einstein’s class at the Luitpold-Gymnasium in Munich with the photo of his class in Aarau. What do you notice about these photos? Discuss this in pairs and write down your answers.

On the right, you will see a painting entitled “Allegory of Friendship”. What is the message of this depiction of Switzerland?
Tick the correct statements.

☐ How Swiss army uniforms were worn correctly around 1900
☐ Protection of the homeland
☐ Alpinism for everyone
☐ Swiss democracy as a fundamental value
☐ Every Swiss man should be armed
☐ Advertising for alpine tourism
☐ Equal rights for men and women
☐ Armed neutrality is typically Swiss
☐ Military service is for men only
☐ Flip-flops are suitable footwear for mountain hikes

“Blind obedience to authority is the greatest enemy of truth.”
Albert Einstein acquires Swiss citizenship

When he began his studies at the Zurich Polytechnic at the age of 17, Einstein was stateless and not affiliated to any particular religion. On 19 October 1899 he applied to the “High Federal Council of the Swiss Confederation in Bern” for “Authorisation to acquire Swiss cantonal and communal citizenship”. Einstein became a Swiss citizen on 21 February 1901 and immediately had to undergo a medical at the district military command, where he was judged unfit for military service.

How did people become Swiss citizens around the year 1900?
What was expected of the applicant?
Tick the correct answers.

- Approval by the Federal Council
- Correctly completed application
- Good financial circumstances
- Positive detective’s surveillance
- Patriotic knowledge
- Basic knowledge of politics
- Fluency in Swiss dialect
- Regular income
- Eagerness to become Swiss
- Holder of a university degree
- Abstinence
- Capacity to work hard
- Marriage to a Swiss person
- Two-year residence obligation
- Payment of naturalisation costs

What requirements must be met nowadays in order to acquire Swiss citizenship?
What are the differences, compared to a hundred years ago?
Discuss these questions in pairs and write down your answers.

“My political ideal is democracy. Everyone should be respected as an individual, but no-one idealised.”
Bern around 1905
After Albert Einstein joined the Patent Office, he married Mileva Marić and their first son was born. Einstein’s work paved the way for a series of new technical possibilities and scientific findings. There was a change in everyday life too – albeit less noticeable.

What was life like for Mileva? Describe her everyday routine around 1905.

On the right, behind the spiral staircase, you will find a reconstructed grocery store. Some of the brands on sale still exist today. Which of these products could Albert Einstein have consumed as early as 1905?

In 1904, a medicinal product came onto the market. This drink was primarily intended to build up people who were in poor physical condition. It was sold at a very reasonable price, too. The first of these products were sold at the chemist’s.
Ingredients: barley malt extract, eggs, milk (the first full nutrition for small children) and – to enhance the taste – a little cocoa. Which product are we talking about?

“I’m doing well; I’m a venerable federal pen-pusher receiving a decent salary.”
First World War, Weimar Republic and the rise of the Nazi Party
The Weimar Republic (1918-1933) emerged after the fall of the monarchy at the end of the First World War. The majority of the population had not yet recovered from the hunger and misery of the final years of the war. The financial scandals of 1923 and 1928 caused much of the population to lose faith in the Weimar Republic. The economic crisis led to political radicalisation and the rise of the Nazi Party.

On the left you will find a showcase containing helmets. What do you notice about these? What does the changing design of the helmets tell you about the way wars were fought before and during the First World War? Discuss this question in pairs and write down your answers.

Look at the films and exhibits. Which weapons and tactics were used during the First World War?

“In order to be an immaculate member of a flock of sheep, one must above all be a sheep oneself.”
What were the characteristics of the Weimar Republic (1918-1933)?
Tick the correct answers.

- Roaring Twenties
- World Economic crisis
- Dictatorship
- Kaiser Wilhelm II reigned over the German Empire
- League of Nations
- Phillip Scheidemann
- Extreme-left activists murder extreme-right politicians
- Parliamentary republic
- President of the German Reich
- National Socialist German Workers’ Party
- Concentration camps
- Inflation
- Chancellor of the German Reich
- German Empire
- Democracy
- War reparation payments
In this room you will find a bust of Adolf Hitler. Look at the objects and writings on display in this part of the exhibition. What were the ideals of the Nazi Party? What were their political aims?

- Annulment of the Treaty of Versailles
- 
- 
- 
- 
- 

What did Albert Einstein fear when he witnessed the rise of the Nazi Party? How did he react to these events?

Helpful hint: see the urgent appeal in German ("Dringender Appell") which he signed in 1932.
Einstein and the atomic bomb

With his famous equation \( E = mc^2 \), Einstein had proved that there was an unbelievably large amount of energy in the core of an atom. During the Second World War, the opposing powers Germany and the US used this knowledge for research on the development of nuclear weapons. This arms race culminated in 1945 in the catastrophe of the atomic bombing of Hiroshima and Nagasaki.

What was the reason for the “Manhattan Project” and what role did Einstein play in it?

Complete the following chronological table:

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Where?</th>
<th>Who?</th>
</tr>
</thead>
<tbody>
<tr>
<td>27/28 September 1905</td>
<td>Energy equals mass multiplied by the speed of light squared ( E=mc^2 )</td>
<td>Bern</td>
<td>Lise Meitner, Otto Robert Frisch, Otto Hahn, Fritz Strassmann</td>
</tr>
<tr>
<td>17 December 1938</td>
<td>Splitting of the atom in Germany</td>
<td>Berlin</td>
<td></td>
</tr>
<tr>
<td>August 1939</td>
<td></td>
<td>Washington DC</td>
<td>Einstein / President Franklin D. Roosevelt</td>
</tr>
<tr>
<td>1941</td>
<td></td>
<td>Various universities and institutes</td>
<td>USA under President Franklin D. Roosevelt</td>
</tr>
<tr>
<td>June 1942</td>
<td>Construction of the atomic bomb</td>
<td></td>
<td>Robert Oppenheimer</td>
</tr>
<tr>
<td>16 July 1945</td>
<td>Test detonation 1st atomic bomb “The Gadget”</td>
<td>White Sands Proving Grounds, Los Alamos</td>
<td>Robert Oppenheimer</td>
</tr>
<tr>
<td></td>
<td>2nd atomic bomb (Uranium 235) “Little Boy” dropped on Hiroshima</td>
<td>Japan</td>
<td></td>
</tr>
<tr>
<td>9 August 1945</td>
<td>3rd atomic bomb (Plutonium 239), “Fat Man” dropped on Nagasaki</td>
<td></td>
<td>USA</td>
</tr>
<tr>
<td>from 2.09.1945 until</td>
<td></td>
<td>Global</td>
<td>USA, Soviet Union, China, Gt. Britain, France, etc.)</td>
</tr>
</tbody>
</table>

“I know not with what weapons World War III will be fought, but World War IV will be fought with sticks and stones.”
Einstein and the atomic bomb

With his famous equation $E = mc^2$, Einstein had proved that there was an unbelievably large amount of energy in the core of an atom. During the Second World War, the opposing powers Germany and the US used this knowledge for research on the development of nuclear weapons. This arms race culminated in 1945 in the catastrophe of the atomic bombing of Hiroshima and Nagasaki.

What was the reason for the “Manhattan Project” and what role did Einstein play in it?

Complete the following chronological table:

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Where?</th>
<th>Who?</th>
</tr>
</thead>
<tbody>
<tr>
<td>27/28 September 1905</td>
<td>Energy equals mass multiplied by the speed of light squared $E=mc^2$</td>
<td>Bern</td>
<td>Lise Meitner, Otto Robert Frisch, Otto Hahn, Fritz Strassmann</td>
</tr>
<tr>
<td>17 December 1938</td>
<td>Splitting of the atom in Germany</td>
<td>Washington DC</td>
<td>Einstein / President Franklin D.Roosevelt</td>
</tr>
<tr>
<td>1941</td>
<td>Various universities and institutes</td>
<td>USA under President Franklin D.Roosevelt</td>
<td></td>
</tr>
<tr>
<td>June 1942</td>
<td>Construction of the atomic bomb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 July 1945</td>
<td>2nd atomic bomb (Uranium 235) “Little Boy” dropped on Hiroshima</td>
<td>White Sands Proving Grounds, Los Alamos</td>
<td>Robert Oppenheimer</td>
</tr>
<tr>
<td>9 August 1945</td>
<td>3rd atomic bomb (Plutonium 239), “Fat Man” dropped on Nagasaki</td>
<td></td>
<td>USA</td>
</tr>
<tr>
<td>from 2.09.1945 until 1989</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

“I know not with what weapons World War III will be fought, but World War IV will be fought with sticks and stones.”
On 1 July 1946, TIME Magazine described Albert Einstein as the “Father of the Atomic Bomb”. Do you agree with this statement? Discuss this question in pairs and write down your arguments.
Post-war economic boom and nuclear arms race

Despite the devastating effects of nuclear arms, many countries wanted to acquire them – even Switzerland discussed the possibility. A veritable nuclear arms race began, in particular between the two superpowers at the time: the US and the Soviet Union. However, up till now the knowledge that in an atomic war there can only be losers has prevented a third world war.

In the furthest exhibition room you will find some picture frames on the wall to your right. The frame in the middle shows what Einstein wrote one year before his death about the profession he would have chosen if he could live his life all over again. Which profession would he have chosen? And what were his reasons for saying this?

Look at the innovations of the 1950s and the documents displayed in this room. What kind of atmosphere prevailed in the US after the Second World War, and how was everyday life?

In politics?

In everyday life?

“The war is won, but the peace is not.”
On this map of the World, show all the places where Albert Einstein lived during his life:
Albert Einstein is considered to have been cosmopolitan. What is meant by this term? Discuss this question in pairs and write down your arguments.
After you have passed the mirrored staircase you will see several screens showing a film with Einstein and a girl on an escalator. What does this film sequence tell you about light?

- The light signal from Einstein’s torch travels faster than the light signal given by the girl on the escalator.
- The girl’s light signal travels faster than Einstein’s.
  - The speed of the escalator plus the speed of light equals the maximum speed of light.
- Einstein’s light signal travels at the same speed as that of the girl.
  - The speed of light is absolute. Nothing travels faster than light.

For which work did Einstein receive the Nobel Prize 1921?
You will find information about this in the next room about Bern.

- Special Theory of Relativity
- Quantum Theory of Light
- Brownian Movement

“When a man sits with a pretty girl for an hour, it seems like a minute. But let him sit on a hot stove for a minute and it will seem like an hour. That’s relativity.”
The Special Theory of Relativity, 1905
The most productive phase of Albert Einstein’s physics research occurred while he was living in Bern. In the exhibition room “Bern, 1902-1909” you will see four screens on the wall at the back of the room entitled “Special Relativity in four lessons. How do we see motion?”

Look at the first three screens and write under each picture the message which it conveys. The following pictures are listed in chronological order.

NB: we will observe two different systems of motion from a stationary standpoint.

What is the basketball player doing while he is standing still?
What is the basketball player doing while he is running along?

Mind game: Let’s move the ball hypothetically into the cosmos. Imagine that the two basketball players are bouncing the ball at the speed of light. What is the relationship between the path of the ball of the running basketball player and that of the stationary basketball player?
If the stationary basketball player bounces his ball at the speed of light, how fast must the running basketball player bounce his ball to keep up with the rhythm of the stationary basketball player?

What is your conclusion?

How does time pass for the running basketball player's ball?
The General Theory of Relativity, 1915

Einstein had based his Special Theory of Relativity on uniformly moving systems. His General Theory of Relativity now introduced the new elements of gravity and acceleration, establishing the equivalence of inertial and gravitational mass. Isaac Newton had represented gravity as an attractive force acting on massive bodies moving in a familiar Euclidean space. In Newton’s theory, the gravitational force acts on massive bodies, but does not act upon radiation such as light. So the theory states that gravity acts on planets to keep them in orbit around a star, but it erroneously predicts that light moves in a straight line uninfluenced by gravity.

Building on the mass-energy equivalence described by Special Relativity, Einstein realised that the path of a light ray is altered by gravity and so in General Relativity he represents the gravity of a massive body as being a distortion of space-time itself. In this geometric description of the Universe, massive bodies, such as a star, distort space-time affecting the motion of both massive bodies and light. Eddington’s observations of 1919 (and many since) confirmed that starlight is bent by gravity, providing the critical observational evidence to support Einstein’s theory.

In the room “Berlin 1914-1933” you will find to the right of the entrance a screen showing the principle of equivalence.

An important principle of General Relativity is the principle of equivalence of inertial and gravitational mass. On the screen, the principle is explained using the examples of a lift and a rocket.

Watch the film and describe what happens in these four pictures.
What is your conclusion?
**C Glossary**

You may find expressions which are unfamiliar to you, either in the exhibition or on the task sheets. This glossary is intended to help you. Please use an (online) encyclopaedia for further research or ask your teacher if there is anything you do not understand.

**Anti-Judaism** General dislike of the history, lifestyle and religion of Jewish people, such as has existed from ancient times until the present day.

**Anti-Semitism** Unlike traditional religiously-motivated dislike of Judaism, this expression refers to the modern type of politically-motivated racist ideology that incites real hatred of the Jews.

**Cold War** The period after the Second World War was marked by an ongoing East-West conflict known as the “Cold War”. Despite the arms race, there was no direct use of weapons but, instead, psychological warfare. The two opposing superpowers - the US and the Soviet Union - stood for the struggle between Capitalism and Communism.

Between 1945 and 1989 (when the Soviet Union collapsed) persistent efforts were made to restrict the sphere of influence of the opposing power and its allies.

**Concentration camp / extermination camp** Concentration camps were initially built to imprison political opponents and people who had fallen out of favour for ethnic, religious or social reasons, thus separating them from the rest of society. Forced labour and re-education were the norm in many concentration camps.

The camps were built in two stages: the Nazi regime set up the first concentration camps as early as 1933. Extermination camps with facilities for mass killings in gas chambers were operated from December 1941 onwards.

From the time of the first concentration camps until liberation of all the camps in 1944/45, well over three million people were murdered in the extermination camps, either in the gas chambers or in mass shootings.

**Diaspora** A Greek word meaning “dispersion”. Used to describe a region inhabited by a religious or national minority and/or a religious or national minority living within such a region.

**Gamma rays / X-rays** X-rays, which were discovered by Wilhelm Conrad Röntgen in 1895, are electromagnetic waves with photon energies between 5 keV and 100 keV (electron volts) and corresponding wavelengths of between 0.25 nanometres (0.25·10⁻⁹ m) and a picometre (10⁻¹² m).

The energy ranges of gamma and X-rays overlap to a great extent. Both are types of electromagnetic radiation and therefore equivalent if the level of energy is the same. The distinguishing criterion is their origin: in contrast to gamma radiation, X-ray radiation is generated not in processes within the atomic nucleus, but through high-energy electron processes.

**Gleichschaltung** An expression coined by the Nazis in 1933 to mean “standardisation”. The aim was total alignment of society and state by 1934 through enforced social and political conformity. Popular activities were centralised in large organisations. Existing organisations were drawn into umbrella organisations run by the Nazis. These measures resulted in the restriction or loss of people’s individual rights, independence, responsibility and freedom. New rules and laws were introduced, and organisations were formed such as the Hitler Youth and the German National Socialist Leagues for students, teachers, lawyers, university lecturers and judges.

**Heuristics** A method of solving a problem, for which no formula exists, based on informal methods or experience and employing a form of trial and error. In the case of Einstein that means he started with a working hypothesis. He began with certain assumptions and his formula/solution would confirm these.

**Holocaust/Shoah** Holocaust (Greek/Latin: “burnt offering”, “sacrifice”) is the term used most often in English-speaking countries to describe the genocide of six million Jews. It began to be used by German-speakers after the broadcast of the TV series “Holocaust” in 1979. Previously, people had talked about the persecution, extermination or murder of the Jews.

Shoah (Hebrew: “extermination”, “destruction”, “catastrophe”) has the same meaning as “holocaust”. The term “Shoah” is generally used in Israel, and some writers prefer it because they consider the religious connotations of “Holocaust” too strong.

**Judaism** The entire Jewish nation describing itself...
as "The Children of Israel" including its culture, history, religion and traditions. Judaism is also one of the major world religions, uniting Jewish, Israeli and Mosaic beliefs. (Mosaic = according to the laws and rituals established by Moses).

**Kosher** Foods which comply with Jewish dietary rules concerning purity and are therefore allowed. According to Jewish tradition, the food that we eat influences not only our bodies but our souls as well.

Examples: foods are controlled and certified by rabbis. Generally speaking, kosher meat is free from blood. Milk and meat dishes must be consumed separately. Fruit and vegetables are considered pure. Kosher fish must have scales and fins. Examples of non-kosher animals are pigs and shellfish.

**Manifesto** A manifesto is a public declaration of aims and intentions, often of a political nature, such as the "manifesto of the Communist Party".

**Shoah** See "Holocaust".

**Synagogue** Jewish place of prayer, which is used for meetings, worship and religious education.

**Talmud** A collection of post-biblical writings. The Talmud is the main scripture of Judaism. It was handed down over several centuries in oral or written form and consists of the "Mishna" (compilation of laws written in Hebrew) and the "Gemara" (analysis and commentary in Aramaic). There are two versions of the Talmud: the older Jerusalem Talmud and the more comprehensive and authoritative Babylonian Talmud. The Talmud does not contain the legal texts themselves, but a commentary on all aspects of Jewish teaching.

**Torah** This expression is mostly used to describe a parchment scroll containing the five books of Moses. Jewish worship in the synagogue includes readings from the Torah.
After visiting the exhibition
Activities to find out more

Albert Einstein and us
A city tour of Bern as Einstein knew it in 1900
Albert Einstein and us

Although some of Einstein’s theories are over a hundred years old, they form the basis for much of our modern technology. Your tour of the exhibition on the life and history of the “Person of the 20th century” (as Einstein was named by TIME Magazine in 1999) will have shown you that Albert Einstein has continued to influence our lives to this day - not only as a scientist, but also as a thinker and activist.

Can you find out which modern everyday objects have their origins in Einstein’s work?
NB: several different products may be based on the same theory.

1905 Photo-electric effect: (light is converted into electricity)
- Remote control
- Laser
- Solar panels

1916 General Theory of Relativity (relativity of time, influence of earth gravitation)
- GPS (Global Positioning System) / Navigation system
- Scanner
- Digital camera

1905 Quantum Theory of Light (stimulated emission)
- CD Player
- Television

If you could meet Albert Einstein today, what questions would you ask him?

..................................................................................................................................................
A city tour of Bern as Einstein knew it in 1900

On a tour of Bern, you and your students will discover places and buildings that Albert Einstein visited regularly. The tour lasts 90 minutes and ends at the Einstein House at Kramgasse 49. There, it is possible to visit the Einstein family’s former apartment, which has been restored in the style of the period around 1900. Booking is requested for groups: www.einstein-bern.ch

Albert Einstein lived in Bern for seven years and he always had happy memories of this time. Having qualified as a teacher of physics and mathematics, he began his career here in 1902 as an assistant teacher. By the time he moved to Zurich seven years later, he had worked his way up to the position of Associate Professor of Physics. During his time at the Federal Patent Office, he continued with the research on his theories and published several articles which broke new ground.

1 Main building of the University of Bern
The new university building on the Grosse Schanze was inaugurated in 1903. The foyer and staircase that Einstein would have crossed between lessons can be visited. Einstein only worked at the University of Bern for a short time: during the summer term in 1908 he held his first seminar as a private lecturer. Only three people attended his lecture on the “Molecular Theory of Heat” and they were not even regular students, but Einstein’s friends and colleagues from the Patent Office.

2 Bollwerk 21
If you take the footbridge from the Grosse Schanze you will arrive at Bollwerk 21. The Café Bollwerk was Einstein’s favourite café. Today it no longer exists. In its place you will find the Restaurant Indiana.

3 Corner of Speichergasse 6 / Genfergasse
From 1902 until 1907 Einstein worked in room 86 of what is nowadays the House of Cantons. He worked there eight hours per day, six days per week, in the Federal Patent Office. About 30 men worked under the authoritarian director Friedrich Haller. In his efforts to achieve success in his career Einstein came up with the formula $A=x+y+z$: “If $A$ is success in life, then $A$ equals $x$ plus $y$ plus $z$. Work is $x$; $y$ is play; and $z$ is keeping your mouth shut.” In the “secular cloister” of the Patent Office he was able to earn his living. The work was challenging and varied, yet he still had enough spare time for his research. Haller found Einstein to be “very useful” and gave him a permanent job as a patent official, with promotion and an increase in salary.

4 Waisenhausplatz 30
Today this building houses the foundation “Stiftung Progr”. At the city gymnasium Einstein was able to carry out experiments privately.

5 Gerechtigkeitsgasse 32
From 1902 Einstein had his first bachelor flat on the first floor of this house. He paid 23 francs rent for the furnished room. He possessed a flimsy suitcase, a few personal belongings and his beloved violin. In Bern he earned his living at first by giving private lessons in mathematics and physics for 2 francs per hour (trial lessons were free) – as well as receiving a little support from his friends and relatives. It was here that he learned of the birth of his illegitimate daughter Lieserl.

6 Kramgasse 49
Albert Einstein and Mileva Marić lived on the second floor of the present-day Einstein House for nearly two years from November 1903. This was Einstein’s third rented accommodation in Bern. He wrote to one of his friends about Mileva: “She looks after everything excellently, cooks well and is always good-humoured.” Their son Hans Albert was born in 1904. Einstein was doing well and he wrote to an acquaintance that he was a “Venerable federal pen-pusher receiving a decent salary.” “In my spare time I ride my old hobbyhorses of mathematics and physics and scrape on my violin – both activities being somewhat limited by my 2-year-old son, who has no time for such things.” Two friends also regularly took up some of his time. They were Maurice Solovine, a Romanian philosophy student who had once taken private lessons with Einstein, and Conrad Habicht, a Swiss mathematician. Together they formed a reading and discussion group which they facetiously named the “Olympian Academy”. Over tea, sausages and cheese, they would discuss mathematical problems, read ancient and modern philosophers like Plato and Spinoza, or study Ernst Mach and Henri Poincaré. After work, Habicht and Solovine would wait for Einstein outside the Patent Office so that they could pursue their discussions.

In 1904 Bern already had a small supply of electricity
thanks to coal-fired steam turbines. But Einstein had no electricity in his apartment on Gerechtigkeitsgasse and he had to go to the supplier with a handcart to fetch his coal.
Solutions
Solutions

A Biography and world history

p. 18

clockwise: Father Hermann, stepdaughter Margaret, first wife Mileva Marić, stepdaughter Ilse, mother Pauline, son Eduard, sister Maja, son Hans Albert, second wife Elsa Einstein (-Löwenthal)

1 Jewish roots

p. 19

Orthodoxy, Zionism, Integration

- Marrying outside their religion
- Integration
- Wearing modern or fashionable clothing
- Attending state schools

2 Ulm 1879–1880

p. 20

- His parents supervised his homework every day.
- Albert Einstein attended Catholic religious instruction at school and Jewish religious instruction from a private teacher.
- As a child, Einstein was an avid reader.
- Einstein’s mother Pauline was well educated, played the piano and was wealthy.
- Einstein received excellent school reports.
- The Einsteins did not cook kosher food.
- The other children called Einstein “Brother Bore” and “Biedermann” (“Petty Bourgeois”).

3 Munich 1880–1894 sec 1

p. 21

- Compass
- Mathematics and geometry books
- Steam-driven engine
- House of cards
- Playing the violin

4 Aarau 1895

p. 22

Photo Munich: Only male students, stiff posture, Einstein’s coat is not buttoned up like those of his classmates, he smiles at the camera (deliberately because of the long period of exposure), very big class.

Photo Aarau: Only male students, relaxed posture such as crossed legs, one student puts his arm on his classmate’s shoulder, everyone is looking in a different direction, small class.

“Allegory of Friendship”
- Protection of the homeland
- Swiss democracy as a fundamental value
- Armed neutrality is typically Swiss

5 Zurich 1896–1902

p. 23

- Approval by the Federal Council
- Correctly completed application
- Positive detective’s surveillance
- Eagerness to become Swiss
- Abstinence
- Capacity to work hard
- Two-year residence obligation
- Payment of naturalisation costs

On 19 October 1899, Einstein applied to the “High Federal Council of the Swiss Confederation in Bern” for “Authorisation to acquire Swiss cantonal and communal citizenship”. The Office of the Attorney General issued a positive report, whereupon the Federal Council granted his request. Afterwards, Albert Einstein was able to send his application to the City Council of Zurich (as Swiss citizenship is granted automatically upon receiving cantonal and communal citizenship, the prior approval of the Federal Council is required). The Zurich authorities appointed Detective Hedinger to draw up a report on Einstein.

The Swiss Federal Office for Migration (www.bfm.admin.ch) provides the following information:

Naturalisation process: regular naturalisation / facilitated naturalisation / renaturalisation

Children born in Switzerland to non-Swiss parents do not automatically receive a Swiss passport. For this, applicants must have resided in Switzerland for at least twelve years. Three of these years must be within the five years immediately preceding the application for Swiss citizenship.

Each year that a person spends in Switzerland between their 10th and 20th year of age counts double. The application must be made to the immigration authorities at the place of residence. These authorities will forward the application to the Federal Department of Justice and Police, where a naturalisation permit will be issued, on condition that the applicant:
- is well integrated into Swiss life
- is familiar with Swiss lifestyle, customs and traditions
- complies with Swiss legal obligations such as the duty to pay income tax and the regulations governing collection and bankruptcy
- is not an internal or external security threat to Switzerland
Since Switzerland is a confederation of states, the applicant will also need to acquire **citizenship of the canton and commune** in which they live. The applicant’s local canton and commune may also have **their own residence and acceptance criteria** as well as charging a naturalisation fee. These conditions may vary considerably from place to place. In some communes, the naturalisation process is relatively liberal, while in others the local citizens vote whether to accept applications for naturalisation. The costs, too, vary from one commune to another and from one canton to another. This means the applicant only acquires Swiss citizenship after he or she has received not only the federal naturalisation permit but also citizenship of the canton and commune of residence. www.bfm.admin.ch

---

6 Bern 1902–1909 sec I

---

As a housewife, Mileva did all the housework and looked after Hans Albert and, later, her second son Eduard. It seems likely that she discussed scientific matters with her husband, but only privately. She also read through his work, but did not take part in the debates of the Olympian Academy. It is possible that the Einstein family gave their washing to a laundry. If not, Mileva would have had to heat up the washing in a coal-heated washtub with an agitator. The pre-heated washing would then have been taken out of the water, soaped and scrubbed by hand.

- Ramseier apple juice
- Cailler chocolate
- Maggi stock cubes
- Suchard chocolate

Riddle: Ovaltine

---

7 Berlin 1914–1933

---

The early helmets are ornate and look impressive. With the outbreak of the First World War, the helmets suddenly become functional, with increasing variations. Then, there are gas masks and steel helmets. The colours change to camouflage.

- Light machine guns as the main weapon of the infantry
- Tanks and anti-tank weapons
- Trenches
- Trench warfare

---

- Civilian population (women and children) employed in munitions factories
- Submarines with torpedoes
- Armed aircraft
- Fragmentation grenades
- Poison gas (gas grenades, steel bottles containing mustard gas, mask-breaking gas)
- Well-developed rail network
- Barbed wire
- Mobile radio network
- 420-mm heavy mortars (similar to cannons)
  - like “Big Bertha”
- Solid rubber tyres
- Armed Zeppelins
- Balloons and airships for reconnaissance
- Combustion engines
- Flame-throwers

---

7 Berlin 1914–1933 sec II

---

He feared the loss of people’s political and personal freedom if the fascists came to power. Einstein openly expressed his radical pacifist ideals,
encouraged conscientious objectors (already in the First World War), supported socialist politics, issued urgent appeals, gave speeches and wrote newspaper articles on the political situation.

**Dringender Appell! (1932)**


---

**8 Princeton 1933–1945 sec I/II**

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Where?</th>
<th>Who?</th>
</tr>
</thead>
<tbody>
<tr>
<td>27/28 Sept-</td>
<td>Energy equals mass multiplied by the speed of light squared E=mc²</td>
<td>Bern</td>
<td>Einstein</td>
</tr>
<tr>
<td>tember 1905</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 December</td>
<td>Splitting of the atom in Germany</td>
<td>Berlin</td>
<td>Lise Meitner, Otto Robert Frisch, Otto Hahn, Fritz Strassmann</td>
</tr>
<tr>
<td>1938</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>August 1939</td>
<td>Letter to the US president asking him to launch America’s own nuclear re-</td>
<td>Washington DC</td>
<td>Einstein / President Franklin D.Roosevelt</td>
</tr>
<tr>
<td></td>
<td>search project</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1941</td>
<td>Start of the “Manhattan-Project”</td>
<td>Various universities and institutes</td>
<td>USA under President Franklin D.Roosevelt</td>
</tr>
<tr>
<td>June 1942</td>
<td>Construction of the atomic bomb</td>
<td>Los Alamos (National Labor-</td>
<td>Robert Oppenheimer</td>
</tr>
<tr>
<td></td>
<td>(The Gadget)</td>
<td>(ory, Los Alamos Desert, New Mexico)</td>
<td></td>
</tr>
<tr>
<td>16 July 1945</td>
<td>Test detonation of 1st atomic bomb “The Gadget”</td>
<td>White Sands Proving Grounds, Los Alamos</td>
<td>Robert Oppenheimer</td>
</tr>
<tr>
<td>6 August 1945</td>
<td>2nd atomic bomb (Uranium 235) “Little Boy” dropped on Hiroshima</td>
<td>Japan</td>
<td>USA</td>
</tr>
<tr>
<td>9 August 1945</td>
<td>3rd atomic bomb (Plutonium 239), “Fat Man” dropped on Nagasaki</td>
<td>Japan</td>
<td>USA</td>
</tr>
<tr>
<td>from 2.09.1945 until 1989</td>
<td>Cold War with nuclear arms race</td>
<td>Global</td>
<td>USA, Soviet Union, China, Gt. Britain, France, etc.</td>
</tr>
</tbody>
</table>

Einstein was wrong in thinking that the Germans were on the point of creating an atomic bomb. It is true that the German scientist Otto Hahn and his team had discovered nuclear fission in their laboratory in 1938, but the German Reich was still a long way from constructing an atomic bomb.
Einstein only made a minor scientific contribution to the creation of the atomic bomb. In 1905, his theory of relativity and his famous equation $E = mc^2$ had merely proved that there was an unbelievably large amount of energy within the core of an atom. Only a week before his death, Einstein signed the “Russell-Einstein Manifesto” against the construction of atomic bombs.

J. Robert Oppenheimer was in charge of the “Manhattan Project” for the development of the atomic bomb. Albert Einstein had encouraged this research. In a letter to US President Roosevelt he warned him that the Nazis could be in a position to construct a super bomb. As a result, the “Manhattan Project” was launched. It resulted in “Little Boy” and “Fat Man”, Hiroshima, Nagasaki and the Cold War.

However, the intellectual father of the atomic bomb was the physicist Leo Szilard, who vehemently opposed the bombing of Japan. As early as the end of 1933, Szilard had conceived of the possibility of a nuclear chain reaction through the release of neutrons. Together, Einstein and Szilard developed the gyrocompass.

In 1934 Szilard filed an application for a British patent describing not only the basic concept of using neutron-induced chain reactions to create explosions, but also the concept of the critical mass. To keep the patent secret (so as not to tip off Germany) he gifted it to the British War Office.

9 Princeton 1945–1955

He said that, if he could do it all again, he would be a plumber.

Einstein’s opinion had been sought on the current situation in the education and science sector. He replied that a scientific career was not worth pursuing in view of the current ideological controls.

In the 1950s the US Senator Joseph McCarthy was vehemently anti-Communist. Like many other intellectuals, Einstein was spied upon during this period. The FBI suspected that Einstein might be involved in “un-American activities” and they compiled a huge file on him containing almost 2000 pages.

In politics?
Anti-Communism, capitalism, Cold War, restriction of liberal basic rights, Marshall Plan.

In everyday life?
Automobile industry, modern technology in everyday family life in the form of televisions, vacuum cleaners and refrigerators. The Hollywood film industry was booming. Private means of transport, consumer society.

Many people identify themselves with the place where they live, their religion and their nationality. No so Albert Einstein. He did not need these criteria to express his identity. The world was his home. He possessed four passports, changed his place of residence over 15 times and described himself as unaffiliated to any religion. However, he admired the cultural heritage of Judaism, which had spread to all continents.

Although he could identify with any democratic form of government, he had pragmatic reasons for becoming a Swiss citizen. He knew he could not study at university or pursue a career as a government official unless he had Swiss nationality. Neither did he refrain from criticising Switzerland for its policy on refugees during the Second World War.
Early in his life, Einstein had begun to adopt an international and universal attitude, which meant going against the tide. During the First World War he criticised the universally acclaimed war and objected to the excessive reparation payments which might cause new conflict. Shortly after the two atomic bombs were dropped on Japan, he said “There is no salvation for civilisation, or even the human race, other than the creation of a world government with laws that will guarantee the safety of the nations. As long as sovereign states continue to have separate armaments and armament secrets, new wars will be inevitable.”

6 Bern 1902–1909 sec II

p. 34
– Einstein’s light signal travels at the same speed as that of the girl. The speed of light is absolute. Nothing travels faster than light.

– Quantum Theory of Light
Albert Einstein received the Nobel Prize “for his services to Theoretical Physics and especially for his discovery of the law of the photoelectric effect.”

p. 35

A basketball player is standing still. He bounces a ball regularly, one metre high per second like the rhythm of a clock.

p. 36

A second basketball player also bounces the ball one metre high per second while he is running along. He bounces the ball regularly, but while he is in motion.

p. 38

Due to gravity, a ball bounces in a curve against the wall of a lift.

The running basketball player’s ball is slower than that of the stationary basketball player because it has a longer path. To keep up with the rhythm of the stationary basketball player, his ball would have to travel faster than the speed of light. BUT...

Conclusion: Because nothing travels faster than light and the running basketball player’s ball cannot travel faster than light, time moves more slowly for the running basketball player’s ball than for the stationary basketball player’s ball.

More slowly.
The rocket is in a vacuum. The ball is weightless and therefore bounces horizontally against the wall.

The lift is in free fall. In free fall there is no gravitational force and so the ball bounces horizontally against the wall.

The rocket accelerates in a vacuum. Due to this acceleration, the ball bounces in a curve.

Conclusion: According to Einstein’s principle of equivalence, acceleration and gravity are of the same nature. During free fall (“Lift in free fall”) the physical phenomena are identical to those in a vacuum (“In the rocket”).

1905 Photo-electric effect: (light is converted into electricity)

1916 General Theory of Relativity (relativity of time, influence of earth gravitation)

1905 Quantum Theory of Light (stimulated emission)

Remote control
Laser
Solar panels
GPS (Global Positioning System) / Navigation system
Scanner
Digital camera
CD Player
Television
Appendix
Literature

Publication on the exhibition
Available from the museum shop


Original edition, English (out of print):

Further literature


List of illustrations

Front page   Albert Einstein Archives, Jerusalem.
p. 7       Compass, Wikimedia Commons.
p. 8       Akademie Olympia, Schweizerisches Literaturarchiv, Bern.
p. 13      Nuclear fission, Wikimedia Commons.
p. 18      Hermann, Pauline, Maja, Margot, Ilse, Eduard, Hans Albert Einstein, Mileva Marić, Albert Einstein Archives, Jerusalem.
p. 18      Elsa Einstein, Deutsches Bundesarchiv.
p. 21      House of cards, Pixabay.
p. 21      Münchner Neueste Nachrichten 1914, Süddeutsche Zeitung online, photo: Oliver Das Gupta.
p. 21      Violin, Pixabay.
p. 21      Wrestling, Deutsches Bundesarchiv.
p. 21      Television 1936/37, Early Television Foundation.
p. 21      Compass, Wikimedia Commons.
p. 21      Football, Wikimedia Commons.
p. 21      Climbing, Pixabay.
p. 21      Steam-driven engine, Wikimedia Commons.
p. 32      Map of the World, Wikimedia Commons.
p. 45      City map Bern, Vidiani Maps, Creative Commons.
p. 50      Map of the World, Wikimedia Commons.

We have made every effort to trace all copyright holders. If we have failed to do so in individual cases, we ask those concerned to contact us.
Imprint

Concept: Ursula Schweizer, Aline Minder
Research: Ursula Schweizer
Editors: Ursula Schweizer, Aline Minder
Proofreading and scientific support (physics and biography): Mirjam Y. Hofer
Proofreading and scientific support (history and biography): Quirinus Reichen
Cooperation task sheets: Valentina Kopp
French translation: Juliane Regler
French proofreading: Vanessa Haussener
English translation: Jenifer Horlent
English proofreading: Sandy Hämerle
Graphics: Bernet & Schönenberger; Dominique Wyss
Illustrations: Sven Jungo

© November 2015
Bernisches Historisches Museum, Helvetiaplatz 5, CH-3000 Bern 6