Chapter 1

Who Was Einstein?

In This Chapter

- Introducing Einstein
- Describing his work and why it was important

About a hundred years ago, an unknown civil servant in Switzerland decided that existing theories in the field of physics were not quite right, and he decided to fix them. What he did was so important that *Time* magazine selected him as the person of the 20th century, ahead of kings, queens, presidents, artists, movie stars, and religious leaders.

Who was Einstein, and what did he do? In this chapter, I introduce you to Einstein's genius, what he discovered, and the importance of his work — topics that get much more detailed attention in subsequent chapters.

Dissecting That Famous Brain

After giving birth to her only son in 1879, Albert Einstein's young mother thought for a moment that he was "a monster." The baby had a strangely shaped and large head. The doctor calmed her down, explaining that it's not uncommon for a baby to have a misshapen head right after birth, and assuring her that the size of his head was going to be just fine. The doctor was right about the size — in just a few weeks, the proportions evened out. But the angular shape of Einstein's head would remain for the rest of his life.

The unusual shape of Einstein's head didn't make him different than other boys. But his brain did. The way his brain worked was anything but ordinary.

When Einstein was alive, many people wondered if his brain was different than other people's. Einstein actually left instructions to make his brain available for research after his death. When Einstein died in 1955, pathologist Thomas Harvey preserved the brain and later performed studies of several tissue samples. Harvey didn't see anything out of the ordinary. However, in 1999, Sandra Witelson of McMaster University in Canada discovered that

Einstein's brain lacked a specific wrinkle that is found on most people's brains. The wrinkle is located in the region of the brain that's related to mathematical thinking and visual imagery.

Touring Einstein's Life

Einstein was apparently better equipped for mathematical and abstract thinking than most people, but it's likely that some other people have had similar native abilities. The shape of his brain alone doesn't explain Einstein's genius. The environment in which he grew up most certainly played a role.

Recognizing his own gifts

As I explain in Chapter 2, Einstein grew up as a fairly normal boy. He was not a child prodigy. He was, instead, a gifted and very independent student. He disliked the strict teaching methods used in the German schools he attended, which caused some friction with his teachers. His independence became teenage rebellion during his high school and college years. Several teachers and professors told him that he wasn't going to amount to anything.

Einstein knew that he was smarter than most people and, while in college, became arrogant and cocky. A couple of his high school teachers and at least one college professor recognized his brilliance. But as has been the case with all great men and women in history, no one ever predicted what he was going to become.

In college, Einstein lived the life of a normal European college student of the late 1800s, hanging out with friends at the local bars. (Some things don't change!) He was popular with women, who found him handsome and charming. He enjoyed being in their company, which caused trouble later in life, when he was married.

Surviving professional disappointment

"A happy man is too comfortable with the present to think much about the future," wrote Einstein in a high school paper for a French class. "If I were lucky enough to pass my college admission tests," he continued in very poor French, "I would attend the Polytechnic Institute to study mathematics and physics. I imagine myself becoming a teacher in those branches."

As I discuss in Chapter 2, when Einstein graduated as a physics major from the Polytechnic in Zurich, he had changed his mind somewhat. He wanted to be a university professor. However, one of the professors he clashed with at the Polytechnic was able to close all the academic doors for Einstein. So instead of becoming a professor, he became a clerk in a Swiss patent office.

From this position, alone and isolated from the academic world, Einstein burst into the world of physics and changed it forever. And he did so mostly in one year. That year, 1905, became known as his *year of miracles* (see Chapter 3).

Becoming famous

The publication of the special theory of relativity, of the famous formula $E = mc^2$, and especially of the general theory of relativity made Einstein famous. (I discuss these revolutionary ideas in detail in Parts III and IV of this book.)

Einstein became an icon. When people imagine a scientist, most think of him. Even the Hollywood portrayals of a scientist often show a middle-aged man, usually in a lab coat, who has disheveled hair, is unconcerned with his clothes, and is engrossed in the task at hand.

Does the stereotype reflect its model? Almost. But Einstein never wore a lab coat. He was a *theoretical* physicist, which means that he needed only a pen and paper — and his mind — to do his job.

Fame made Einstein mellow. He was very aware of his status as the greatest scientist in the world. But he never pulled rank. Most people who knew him found him to be kind and caring. As a physicist, I would've loved to have met him, but my life didn't overlap with his. However, I know a few scientists who were fortunate enough to meet him. The arrogance of his youth was long gone, and the Einstein they met was a gentle man who made them feel at ease.

Even people who were his professional equals, like Niels Bohr and Wolfgang Pauli, were in awe of him. In the late 1940s, Abraham Pais, then a young physicist at the Institute for Advanced Studies in Princeton, New Jersey (where Einstein worked after he immigrated to the United States), noticed a different attitude in both Bohr and Pauli whenever Einstein was around.

Lacking fortune

Einstein's fame didn't translate into wealth. He was never much interested in material things, but he did have a love for both music and sailing.

Even as late as 1922, Einstein couldn't put together the money to buy a weekend cottage on the water near Berlin and a sailboat. His salary as a professor at the University of Berlin wouldn't stretch enough to pay for these luxuries. He settled for renting a small house in the country.

For his 50th birthday, a group of friends bought Einstein a 21-foot mahogany-fitted boat. But Einstein would enjoy sailing it for only a few years. The threat of Nazi Germany forced him to leave Europe for the United States in 1933. His beloved boat was confiscated and sold by the Nazi regime as the property of an enemy of the state.

Einstein won the Nobel Prize in physics in 1922. The prize brought with it a considerable amount of money, which he gave to his former wife for the care of their children.

After Einstein came to the United States, his fortunes improved. His initial salary at the Institute for Advanced Studies was $16,000 a year, about twice that of a full professor at the time. (Because other recognized scientists also made high salaries, a few people commented that the institute was not just for “advanced study” but for “advanced salaries.”) But Einstein’s lifestyle continued to be modest. His house at 112 Mercer Street in Princeton was an average house in a middle class neighborhood.

Playing peaceful politics

Einstein used his fame to speak out on political causes that he felt strongly about. “My political ideal is democracy. Let every man be respected as an individual and no man idolized,” he wrote in 1931. “It is an irony of fate that I myself have been the recipient of excessive admiration . . . through no fault, and no merit, of my own.”

His two main political concerns were pacifism and the creation of a world government that would enforce disarmament. He long swore that he would never support wartime activities. But the rise of Nazi Germany changed his perspective somewhat, and he became what he called a “militant activist.”

Although Einstein played no direct role in developing the atomic bomb, his $E = mc^2$ equation opened the door to its creation (but didn’t lead directly to it). And Einstein did encourage the United States government to pursue an atomic weapon, out of fear that the Nazis might be doing the same. As I explain in Chapter 17, Einstein sent a letter to President Franklin Delano Roosevelt in 1939, bringing the threat of a Nazi atomic bomb to his attention. The letter didn’t lead to the bomb’s development, but nonetheless Einstein later called it “the greatest mistake” of his life.

Working and playing

Einstein had an uncommon ability to work even in the midst of personal tragedy. Even as a child, he was somewhat detached from external events. But he wasn’t aloof or incapable of personal relationships. It’s just that his work and his thinking came first. “Nothing tragic really gets to him,” wrote his second wife, Elsa, after the death of her daughter (Einstein’s stepdaughter). “He is in the happy position of being able to shuffle it off. That is also why he can work so well.”

When Einstein was growing up, his mother made sure that he and his sister, Maja, were exposed to music. Einstein took violin lessons and later learned to play the piano on his own. Music became his lifelong love. He liked Mozart, Schubert, Bach, Beethoven, Vivaldi, Corelli, and Scarlatti.

Einstein also appreciated art, preferring the old masters. He thought that they were more “convincing.” Of the modern masters, he was interested in the pre-cubist period of Picasso (the period around 1905, when Picasso’s palette started to lighten, with paintings of clowns and harlequins).

In spite of two failed marriages and the rise of Nazism in his homeland, Einstein lived a generally happy life. For the most part, his life was his work, and his work was as meaningful as that of Isaac Newton’s. (I discuss Newton’s contributions in Part II of this book.) The two men have no equals in the history of science.

Appreciating His Contributions

The 18th-century mathematician Joseph-Louis Lagrange once complained that there was only one universe and Newton had already discovered how it worked. Einstein proved Lagrange (and other scientists, who thought that the field of physics was essentially complete) wrong. Einstein showed that Newton’s laws didn’t tell the whole story, and he proceeded to tell us how the universe really works.

The special theory of relativity

Newton’s universe works like clockwork, obediently following the laws that Newton discovered. In this universe, clocks run at the same rate for everyone, and space is the stage where things happen.

NEW IDEA

With his special theory of relativity (which is called *special* to distinguish it from the extended *general* theory of relativity, which came later), Einstein showed us that time and space aren’t fixed. Instead, each one of us measures time differently depending on how we move, and space contracts or expands as we speed up or slow down.

Einstein’s strange conclusions came out of a single important insight: The speed of light is always the same, regardless of how fast you move toward or away from a light source. This assumption goes against common sense.

Consider these examples: Say you're in a car traveling 50 mph, and the car next to you is going at the same speed. If you look into the car next to you (without catching a glimpse of the horizon speeding by), it appears to be standing still. While both speedometers read 50, from your perspective, the other car isn't moving.

Now, say you're traveling on a spaceship at half the speed of light (which Einstein represents with the letter *c*). You see a beam of light traveling through space at 300,000 kilometers (186,000 miles) per second. What if you speed up? The speed of light remains the same. What if you slow down? No difference. No matter how fast you go, you still measure light traveling at *c*.

TIP

If you and I are moving relative to each other and we both measure the same speed of light, what does that mean? It means that your space and your time are different from my space and my time. In Einstein's universe, space and time are linked to each other, and when you change one, the other changes. But the combination of the two, the four-dimensional entity called *spacetime,* stays unchanged. Your spacetime is my spacetime, and your speed of light is my speed of light. In this way, not everything is relative, as many people think. Spacetime and the speed of light are not relative. They are absolute, as physicists say. And that's what makes everything in the universe work.

Einstein's conclusions about the nature of space and time have not only been seen and measured many times over the last half century; they are actually used in the design of delicate laboratory equipment. His special theory clarified our understanding of the world and corrected previous inconsistencies. I discuss the special theory in detail in Part III.

$E = mc^2$

This is the most famous equation of all. It's the one equation that most people on the planet can recognize. And it came out of Einstein's theory of relativity. You'd think that given its importance, it would take pages and pages of complicated mathematical derivations and a very long paper to present it. Einstein's paper on his equation was all of three pages long. And the math was simple (if you're good at math).

NEW IDEA

$E = mc^2$ says that mass and energy are the same thing and that objects usually have both. Mass can be converted into energy and energy into mass. The equation explains how the sun works, a mystery that had puzzled scientists until Einstein came along.

Einstein's mass-energy equation is used today by medical physicists to calculate the energies generated in particle accelerators used in cancer treatment. It's used in the design of machines like the positron emission tomography (PET) scanner. It's used in the design of smoke detectors.

And, as I note earlier in the chapter, the equation (but not Einstein) played a role in the calculations for the atomic bomb invented at Los Alamos National Laboratory and later dropped over Japan, ending War World II.

Quantum theory

In Newton's universe, if you had enough computing power at your disposal, you could input all the information that you know about the universe now, run a program based on Newton's laws, and be able to call up any event in the universe's past or predict any event in its future. You could input a time and place into your computer and get a complete description of that place at that time, even if the time were in the future.

Yes, that's right, you could predict the future! At first, that ability sounds wonderful. You could know what the first human colonies on Mars will look like or what civilization on Earth will be like in 500 or 1 million years. Or — even more importantly — you could find out who will win the Super Bowl next year. But would you like to know the exact details of the painful events that lie ahead? Wouldn't it be horrible to know exactly when and how they will happen?

Not to worry. Einstein took care of that dilemma for us. You can't predict the future. And nobody will ever be able to, regardless of how powerful their computers are. At least not if quantum physics is right. And all evidence tells us that, in its basic premise, it is.

NEW IDEA

Quantum physics began with Einstein's 1905 paper explaining the *photoelectric effect,* the principle behind photocells that convert sunlight into electricity. Einstein didn't just explain the effect. Characteristically, he went to the heart of physics and showed us how the world is made. In this paper, Einstein said that light is made up of indivisible bundles of energy that we now call *quanta.* What's more important, he said that when light interacts with matter, light is absorbed or emitted in the same indivisible energy bundles. This last assumption became the basis for the physics of the atom.

But Einstein's idea of the quantum of energy, which later on became known as the *photon,* encountered a great deal of resistance. Only when experiments 15 years later proved that Einstein was right, physicists finally came around and embraced the idea. Within a few months, quantum physics, the physics of the atom, was born.

TIP

Quantum physics says that you can't know at once everything you'd want to know about a subatomic particle. Matter is made up of things we call electrons and quarks and other equally exotic particles. And you are limited by nature in what you can know about them. The world has a built-in uncertainty that prevents you from knowing *exactly* how things are going to turn out. You can calculate only the probabilities of outcomes of events. If you measure an electron at one location, there's a certain probability that when you look for it at another location, you'll find it.

Subatomic particles and dust particles

A subatomic particle shares only its name with what we call *particles* in our regular daily experience. A dust particle, for example, has mass, size, shape, and even some color. A subatomic particle is called a particle only because that's what scientists thought they were looking at when they first began to learn about these entities during the late 19th and early 20th centuries. But the things that make up atoms turned out to be nothing like dust particles. Scientists figured this out only in the 1920s, after the term *particle* was widely used to refer to parts of the atom, so they didn't bother to invent a new name. They know what they mean when they use the word, even though nonscientists find it confusing.

Scientists have learned to work with these slippery particles and are able to manipulate them with great precision. A television set, for example, uses jets of electrons that are directed at different points on the screen to form the images that you see. (Of course, sometimes the images they form aren't worth seeing, but that's another discussion completely!)

If the only thing you know about these electrons is probabilities, you may be able to predict with good accuracy where the relatively few electrons in your TV set will hit the screen, but you won't be able to predict what the tremendous collection of electrons and other particles that make up your brain will do next. The future is as uncertain as you always thought it was, and no technological advances are going to change that. That's the way the world is.

Einstein, who started quantum physics, never really believed that this view of the world was the final word. He thought that quantum physics was temporary and that one day we would discover the hidden world underneath — a world that isn't probabilistic.

Sophisticated experiments done during the last 20 years have convinced physicists that, in this case, Einstein was wrong. The world that quantum physics shows us is the real world. And I give you a detailed introduction to that world in Part V.

The general theory of relativity

The special theory of relativity applies only when you're moving at a steady speed and along a straight line. If you turn or accelerate, special relativity ceases to apply. Einstein wanted to extend his theory to all motion, accelerated or not.

That proved difficult to do.

Whereas the theory of special relativity took Einstein only a few weeks to develop, he needed four years to extend the theory to all motion. In the process, he had to learn a whole new area of mathematics. When he was done, he'd produced what's considered to be the most beautiful scientific theory ever discovered. He called it the general theory of relativity.

General relativity says that a large object, like the Earth or the sun, warps the space around it, and gravity is nothing more than the result of that warping. The Earth itself doesn't keep you firmly on the ground. Instead, the space around the Earth is warped, and the slope of that warped space keeps you on the ground.

Because the sun warps space, a ray of light passing close to the sun will bend. General relativity also says that a clock runs more slowly in a stronger gravitational field. For example, a clock will run more slowly in your basement than in your attic. (However, the difference is so slight that you couldn't measure it even if you had the most precise atomic clock and extremely accurate equipment.)

Even before he was finished with it, Einstein wanted to test his theory, to make sure that he was on the right track. He knew that the motion of the planet Mercury hadn't been completely explained and that astronomers were puzzled by that problem. Einstein used his theory to calculate the correct orbit of Mercury, explaining that a small discrepancy in the observations was the result of the warping of space around the sun.

After Einstein published his theory, the English astronomer Arthur Eddington organized an expedition to Africa to measure the bending of light from a star during a total eclipse of the sun (the only time that the stars and the sun are visible at the same time). The results of the measurements confirmed Einstein's prediction. The confirmation thrilled the world, and Einstein became famous almost immediately. I devote Part IV of this book to explaining why this theory had such a profound impact.

Other contributions

As if relativity, $E = mc^2$, and quantum theory weren't enough, Einstein made other significant contributions to physics. Following is a sampling.

Proving molecules are real

In two of the five papers that Einstein published in 1905 (see Chapter 3), he showed that molecules are real and explained how you'd go about measuring them and studying their motions. At the time, not everyone was convinced that atoms existed. These two papers, in conjunction with two others that he'd published earlier, proved once and for all that molecules are real and measurable.

Stimulating radiation

Soon after he completed his general theory of relativity, Einstein began to think about the absorption and emission of radiation. He discovered a method for stimulating the emission of radiation from certain atoms. That discovery is the basis for the laser, invented 40 years later by Charles Townes.

Creating a model of the universe

Einstein decided to use his theory of relativity to build a model of the universe. The task turned out to be extremely difficult. When Einstein was done, he had a universe that was changing and moving, either expanding or collapsing. He didn't like the results. Observations of the time showed that the universe was static, so he introduced a term into his equations — a cosmological constant — that allowed the model to show a static universe as well.

Twelve years later, the astronomer Edwin Hubble discovered that the universe isn't static after all. It expands.

By making his model conform to what was believed at the time, Einstein missed the chance to predict the expansion of the universe. I discuss this apparent blunder in Chapter 18.

Many years after Einstein's death, scientists realized that his cosmological constant *does* belong in the equations for the universe. It's needed to explain the very accurate observations that the Hubble Space Telescope and other NASA spacecraft are currently making. Einstein was right after all, as I show you in Chapter 19.

Standing in Awe

The enormous progress in physics and astronomy that has taken place during the last century is due almost completely to the work that Einstein did between 1905 and 1917. If Einstein hadn't existed, most of his work would've been done eventually by other physicists. Some discoveries would've been made a few years after Einstein made them, while others would've taken decades longer. The general theory, his greatest achievement and the one with the greatest implications, wasn't on anybody's radar screen at the time Einstein developed it. Would scientists have discovered it by now? No one can tell.

But Einstein did live, and he did develop his revolutionary theories. To a great extent, the world is what it is today because of him. And it all started in a patent office in Bern, Switzerland, a century ago.