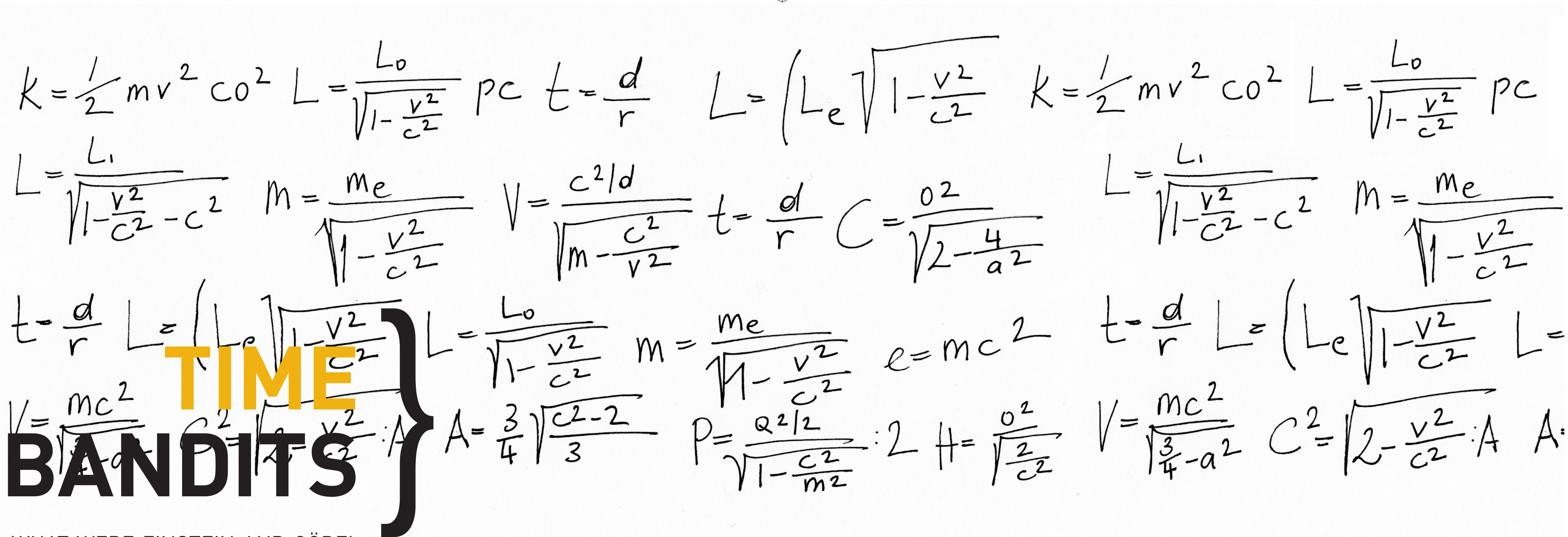


TIME BANDITS

WHAT WERE EINSTEIN AND GÖDEL TALKING ABOUT?

BY **JIM HOLT**

In 1933, with his great scientific discoverie behind him, Albert Einstein came to America He spent the last twenty-two years of his life i Princeton, New Jersey, where he had bee recruited as the star member of the Institute fo Advanced Study. Einstein was reasonabl content with his new milieu, taking it pretensions in stride. “Princeton is a wonderfu piece of earth, and at the same time a exceedingly amusing ceremonial backwater o tiny spindle-shanked demigods,” he observed His daily routine began with a leisurely wal from his house, at 115 Mercer Street, to hi office at the institute. He was by then one o the most famous and, with his distinctiv appearance—the whirl of pillow-combed hair the baggy pants held up by suspenders—mos recognizable people in the world

A decade after arriving in Princeton, Einstein acquired a walking companion, a much younger man who, next to the rumpled Einstein, cut a dapper figure in a white linen suit and matching fedora. The two would talk animatedly in German on their morning amble to the institute and again, later in the day, on their way homeward. The man in the suit may not have been recognized by many townspeople, but Einstein addressed him as a peer, someone who, like him, had single-handedly launched a conceptual revolution.

If Einstein had upended our everyday notions about the physical world with his theory of relativity, the younger man, Kurt Gödel, had had a similarly subversive effect on our understanding of the abstract world of mathematics.

Gödel, who has often been called the greatest logician since Aristotle, was a strange and ultimately tragic man. Whereas Einstein was gregarious and full of laughter, Gödel was solemn, solitary, and pessimistic. Einstein, a passionate amateur violinist, loved Beethoven and Mozart. Gödel’s taste ran in another direction: his favorite movie was Walt Disney’s “Snow White and the Seven Dwarfs,” and when his wife put a pink flamingo in their front yard he pronounced it furchtbar herzig—“awfully charming.” Einstein freely indulged his appetite for heavy German cooking; Gödel subsisted on a valetudinarian’s diet of butter, baby food, and laxatives. Although Einstein’s private life was not without its complications, outwardly he was jolly and at home in the world. Gödel, by contrast, had a tendency toward paranoia. He believed in ghosts; he had a morbid dread of being poisoned by refrigerator gases; he refused to go out when certain distinguished mathematicians were in town, apparently out of concern that they might try to kill him. “Every chaos is a wrong appearance,” he insisted—the paranoiac’s first axiom.

A century ago, in 1905, Einstein proved that time, as it had been understood by scientist and layman alike, was a fiction. As it began, Einstein, twenty-five years old, was employed as an inspector in a patent office in Bern, Switzerland. Having earlier failed to get his doctorate in physics, he had temporarily given up on the idea of an academic career, telling a friend that “the whole comedy has become boring.” He had recently read a book by Henri Poincaré, a French mathematician of enormous reputation, which identified three fundamental unsolved problems in science. The first concerned the “photoelectric effect”: how did ultraviolet light knock electrons off the surface of a piece of metal? The second concerned “Brownian motion”: why did pollen particles suspended in water move about in a random zigzag pattern? The third concerned the “luminiferous ether” that was supposed to fill all of space and serve as the medium through which light waves moved, the way sound waves move through air, or ocean waves through water: why had experiments failed to detect the earth’s motion through this ether?

Each of these problems had the potential to reveal what Einstein held to be the underlying simplicity of nature. Working alone, apart from the scientific community, the unknown junior clerk rapidly managed to dispatch all three. His solutions were presented in four papers, written in the months of March, April, May, and June of 1905. In his March paper, on the photoelectric effect, he deduced that light came in discrete particles, which were later dubbed “photons.” In his April and May papers, he established once and for all the reality of atoms, giving a theoretical estimate of their size and showing how their bumping around caused Brownian motion. In his June paper, on the ether problem, he unveiled his theory of relativity. Then, as a sort of encore, he published a three-page note in September containing the most famous equation of all time: E = mc2.

All of these papers had a touch of magic about them, and upset deeply held convictions in the physics community. Yet, for scope and audacity, Einstein’s June paper stood out.

ARE WE TO THINK THAT 2 + 2 IS NOT 4, BUT 4.001?

In thirty succinct pages, he completely rewrote the laws of physics, beginning with two stark principles. First, the laws of physics are absolute: the same laws must be valid for all observers. Second, the speed of light is absolute; it, too, is the same for all observers. The second principle, though less obvious, had the same sort of logic to recommend it. Since light is an electromagnetic wave (this had been known since the nineteenth century), its speed is fixed by the laws of electromagnetism; those laws ought to be the same for all observers; and therefore everyone should see light moving at the same speed, regardless of the frame of reference. Still, it was bold of Einstein to embrace the light principle, for its consequences seemed downright absurd.

Gödel entered the University of Vienna in 1924. He had intended to study physics, but he was soon seduced by the beauties of mathematics, and especially by the notion that abstractions like numbers and circles had a perfect, timeless existence independent of the human mind. This doctrine, which is called Platonism, because it descends from Plato’s theory of ideas, has always been popular among mathematicians. In the philosophical world of nineteen-twenties Vienna, however, it was considered distinctly old-fashioned. Among the many intellectual movements that flourished in the city’s rich café culture, one of the most prominent was the Vienna Circle, a group of thinkers united in their belief that philosophy must be cleansed of metaphysics and made over in the image of science. Under the influence of Ludwig Wittgenstein, their reluctant guru, the members of the Vienna Circle regarded mathematics as a game played with symbols, a more intricate version of chess. What made a proposition like “2 + 2 = 4” true, they held, was not that it correctly described some abstract world of numbers but that it could be derived in a logical system according to certain rules.

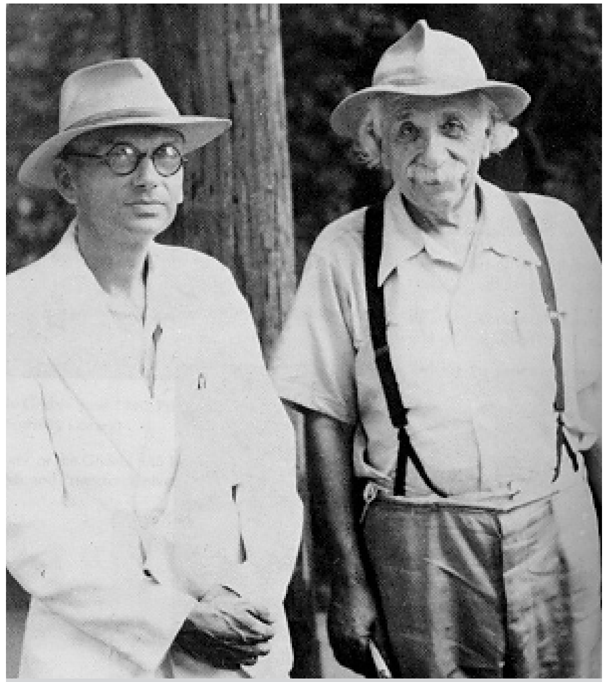
Gödel was introduced into the Vienna Circle by one of his professors, but he kept quiet about his Platonist views. Being both rigorous and averse to controversy, he did not like to argue his convictions unless he had an airtight way of demonstrating that they were valid. But how could one demonstrate that mathematics could not be reduced to the artifices of logic? Gödel’s strategy—one of “heart-stopping beauty,” as Goldstein justly observes—was to use logic against itself. Beginning with a logical system for mathematics, he invented an ingenious scheme that allowed the formulas in it to engage in a sort of double speak. A formula that said something about numbers could also, in this scheme, be interpreted as saying something about other formulas and how they were logically related to one another. In fact, a numerical formula could even be made to say something about itself. Having painstakingly built this apparatus of mathematical self-reference, Gödel came up with an astonishing twist: he produced a formula that, while ostensibly saying something about numbers, also says, “I am not provable.”

GÖDEL, WHO HAS OFTEN BEEN CALLED THE GREATEST LOGICIAN SINCE ARISTOTLE, WAS A STRANGE AND ULTIMATELY TRAGIC MAN.

At first, this looks like a paradox, recalling as it does the proverbial Cretan who announces, "All Cretans are liars." But Gödel's self-referential formula comments on its provability, not on its truthfulness. Could it be lying? No, because if it were, that would mean it could be proved, which would make it true. So, in asserting that it cannot be proved, it has to be telling the truth. But the truth of this proposition can be seen only from outside the logical system. Inside the system, it is neither provable nor disprovable. The system, then, is incomplete. The conclusion—that no logical system can capture all the truths of mathematics—is known as the first incompleteness theorem. Gödel also proved that no logical system for mathematics could, by its own devices, be shown to be free from inconsistency, a result known as the second incompleteness theorem.

Wittgenstein once averred that "there can never be surprises in logic." But Gödel's incompleteness theorems did come as a surprise. In fact, when the fledgling logician presented them at a conference in the German city of Königsberg in 1930, almost no one was able to make any sense of them. What could it mean to say that a mathematical proposition was true if there was no possibility of proving it? The very idea seemed absurd. Even the once great logician Bertrand Russell was baffled; he seems to have been under the misapprehension that Gödel had detected an inconsistency in mathematics. "Are we to think that 2 + 2 is not 4, but 4.001?" Russell asked decades later in dismay, adding that he was "glad [he] was no longer working at mathematical logic." As the significance of Gödel's theorems began to sink in, words like "debacle," "catastrophe," and "nightmare" were bandied about. It had been an article of faith that, armed with logic, mathematicians could in principle resolve any conundrum at all—that in mathematics, as it had been famously declared, there was no ignorabimus. Gödel's theorems seemed to have shattered this ideal of complete knowledge.

That was not the way Gödel saw it. He believed he had shown that mathematics has a robust reality that transcends any system of logic. But logic, he was convinced, is not the only route to knowledge of this reality; we also have something like an extrasensory perception of it, which he called "mathematical intuition." It is this faculty of intuition that allows us to see, for example, that the formula saying "I am not provable" must be true, even though it defies proof within the system where it lives. Some thinkers have taken this theme further, maintaining that Gödel's incompleteness theorems have profound implications for the nature of the human mind. Our mental powers, it is argued, must outstrip those of any computer, since a computer is just a logical system running on hardware, and our minds can arrive at truths that are beyond the reach of a logical system. Gödel was twenty-four when he proved his incompleteness theorems.



KURT GÖDEL AND ALBERT EINSTEIN IN 1954

The political situation in Austria was becoming ever more chaotic with Hitler's rise to power in Germany. In 1936, the Vienna Circle dissolved, after its founder was assassinated by a deranged student. He resolved to leave for Princeton, where he had been offered a position by the Institute for Advanced Study. But, the war having broken out, he judged it too risky to cross the Atlantic. So he took the long way around, traversing Russia, the Pacific, and the United States, and finally arriving in Princeton in early 1940. At the institute, Gödel was given an office almost directly above Einstein's. For the rest of his life he rarely left Princeton, which he came to find "ten times more congenial" than his once beloved Vienna.

It was thus that Einstein made the transition from his "special" theory of relativity of 1905 to his "general" theory, whose equations he worked out over the next decade and published in 1916. What made those equations so powerful was that they explained gravity, the force that governs the over-all shape of the cosmos. Decades later, Gödel, walking with Einstein, had the privilege of picking up the subtleties of relativity theory from the master himself. Einstein had shown that the flow of time depended on motion and gravity, and that the division of events into "past" and "future" was relative.

Gödel took a more radical view: he believed that time, as it was intuitively understood, did not exist at all.