Things and Thoughts

PETER GALISON

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My first idea of Einstein—in fact of anything at all about science—came from my great-grandfather, Frank Alexander, who studied at the Technical University in Berlin and arrived in the United States from Germany late in the nineteenth century. Frank Alexander came from a long line of engineers, but he was the first to switch from civil engineering to electrical and radio engineering. Around the turn of the century, he worked in Thomas Edison's laboratory complex in New Jersey. Then, with various patents he had taken, he launched a small electrical firm of his own in Manhattan, which manufactured various equipment ranging from electric lights to high-voltage testing devices.

Some of my earliest, happiest memories are of going down into his basement laboratory. From a house full of overstuffed chairs and oil paintings, we'd descend into a large, somewhat dimly lit room that had been divided into aisles of long metal floor-to-ceiling shelves stuffed with ammeters and voltmeters, switches, glassware, motors, and coils. For almost a decade—he died when I was fourteen or so—that dusty, hidden redoubt was exactly my image of what a real scientific laboratory should be. Bottles of mercury lined the shelves (I shudder now to think of the many hours I spent playing with the stuff). There were lathes, which spewed out curled metal shavings when he made custom screws and joints for his work. On one wall, like something out of Dr. Frankenstein's work space, were mounted enormous double-throw switches. There were neon and phosphorescent lights he had designed in various shapes, some with glowing flowers and leaves—when he was younger, he had even blown his own glassware. The whole place stank of ozone (I came to love that smell of happy toxicity) as he shot crackling blue sparks from gun-shaped electrodes to illuminate the little neon lights. I found this world completely entrancing—the beautiful coils of thin copper wire I could make out in the innards of his electrical meters, the beautifully finished brass contact posts mounted on black Bakelite stands.

Once a week, on Saturday, he would go to the venerable patent room at the New York Public Library, where he would sift through American, French, and German publications to see what had been done in his area. Then it was back to the laboratory to invent something brand-new.

All this struck me, at the time, as of a piece with the imagined technological future, the science that everyone was talking about but that wasn't quite accessible to me: rocket countdowns on television, IBM computers in the glossy magazines. But my great-grandfather's basement laboratory was actually very much in the past. I'm certain that he and transistors never met. His desk upstairs, too, with its neat stack of precision technical drawings bearing his carefully written marginal commentary in fountain-pen ink, was more reminiscent of pre–World War I Europe. Or maybe, to be more precise, what I was seeing was the future of the past—of the electric lights and transformers that in Edison's New Jersey laboratory had promised something unclear but new and hopeful for the world after 1900. Whatever it was, I was crazy about it—and by extension, about everything electrical.

One day when I was eleven or so, I made a tic-tac-toe computer, the whole thing wired somewhat chaotically with switches and bulbs onto some scrap lumber. By then, my great-grandfather was just about blind. He was sitting in his garden chair by the bird feeder, and I told him what I had done with the copper strips and the screws and the yards of orange-colored wire. He asked me to show it to him. Slowly, my own Albert Einstein ran his fingers along the wires, testing to make sure the connections were good, and explained to me very precisely how I could simplify it.

In seventh grade, I had a science teacher who, unlike any of my previous teachers, actually knew some physics. I told him about my fascination with electricity and magnetism, and he showed me, step by step, how Einstein, using basic ideas about the speed of light and coordinated clocks, had concluded that a moving bar would be measured as shorter when compared with a bar at rest and how moving clocks went slower than motionless ones. It was a stunning moment for me. I had managed to get a ham radio license, but I had never seen anything interesting derived in physics. This was magic! I copied over the argument many times, slowly, like the words of a prayer. I can still picture my Δx's and Δt's in heavy pencil on the lined pages of my notebook.

In retrospect, it seems so woefully partial. I didn't know any classical physics—in fact I knew just about nothing of science other than how to take apart (and sometimes even fix) the broken vacuum-tube radios I cadged from local repair shops. But I thought that this argument of Einstein's was the most astonishing thing I had ever heard: you could begin with simple assumptions and figure out something completely unexpected about the world.

I fell in love with physics. (Much to my later regret—indeed, it should never have been allowed—I managed to learn almost no biology.) It was politically difficult to hold on to a dream of physics in high school, with the country in the middle of the Vietnam War. My friends considered hard science a short step from the manufacture of plastic shrapnel. I took physics by myself, after hours, from a sympathetic teacher—samizdat pulleys and covert capacitors. I ended up graduating early, and spent the following year in Paris, where the École Polytechnique let me work with a wonderful researcher in a plasma physics laboratory and audit a math course in distributions and convolutions given by the great mathematician Laurent Schwartz. Again—and indeed still today—I was riveted by the fact that the symbols on the page, those abstract musings, somehow linked up with the oscilloscopes, copper wires, and machines on the laboratory floor.

This contact point between abstraction and concreteness has remained a central theme of my work. As a student in Paris, I started reading Einstein's papers, pursuing that union of machine reasoning and abstract concepts I found so compelling about his work. It was not the celebrated Einstein who interested me; it was quite distinctly the younger Einstein, the Einstein who grew up around his father's and uncle's electrotechnical company, the Einstein who spent his university days messing with experiments in the basement, ducking out of the remarkable mathematical lectures given by greats like Hermann Minkowski. When I returned to the United States and started college, I read Thomas Kuhn's *The Structure of Scientific Revolutions* and Gerald Holton's *Thematic Origins of Scientific Thought;* both showed me a new side of Einstein's work, one connected to history and philosophy. Those books extended the connections and opened up for me the possibility of thinking about Einsteinian physics in a completely new way.

What now seems to me something of a minor obsession continued during my undergraduate years; for one summer, at the Institute for Advanced Study in Princeton, I worked on the Einstein Papers publication project, which was just then getting under way. I found it extraordinary to see how deeply Einstein had been engaged with detailed discussions of inventions and patents. For my Ph.D. thesis in the history of science (which became my first book, *How Experiments End*), I used the case of Einstein's work on the gyrocompass—a nonmagnetic way of tracking one's orientation—to show how technological concerns, the grit of the basement, lay behind some of Einstein's most abstract thought experiments. The gyrocompass became for Einstein a model of the atom. Pure physics met applied engineering.

This preoccupation led many other places. I became fascinated by detectors, those machines that translate the invisibly small into a larger world where their interactions match up against the great synthetic accounts of high-energy theory. My great-grandfather's laboratory bench—and, later, Einstein's—spurred an interest in laboratory architecture. The electrical universe I had glimpsed long ago in that New York City laboratory and the patent papers of Einstein have led, more recently, to an examination of the ways in which Einstein and Henri Poincaré, in different ways, used the idea of clock coordination as they formulated their ideas on the relativity of time.

Much as I admire the older Einstein—much as I find him an admirable figure for his political courage in opposing McCarthyism, nuclear escalation, and racism, much as I see the bravery behind his pursuit of a unified field theory—it is the younger Einstein who has meant the most to me. There is a turn in Einstein's later life and work that (though I sympathize with it) breaks its connection with me—a move away from the engagement with things and thoughts that characterized him as a younger scientist. I don't think this change of focus was purely intellectual. I think the Nazis' rise to power and his exile from Europe were deeply traumatic to Einstein—more so than is evident from his public pronouncements. After the Holocaust, he found it impossible to reestablish contact with Germany, but not only with Germany. I think that in a certain sense he stepped back from the world. It is as if from the intimate connection of things with thought, only thought survived. Of course, the horror in Europe was not the only reason for his farewell to the laboratory; idiotically, the American security services considered him a threat and excluded him from the important war work (though he did do some work on the theory of torpedoes). No doubt, too, his increasing fame created an awkwardness in his interaction with other physicists. The Institute for Advanced Study gave him the peace he craved, a place where he could talk at length with a few select friends, especially Kurt Gödel. Yet there was a very great distance between those long walks in exile and the turbulent, productive chaos of his early years, those years of the basement lab, when he was experimenting on magnetism, working on general relativity, exploring quantum mechanics, and testifying about gyrocompasses.

When I think about Einstein, I always come back to my great-grandfather's laboratory, to those thin tubes of neon we lit with the crackle of a spark. The vestiges of 1900 were in his fingers as he showed me how to design circuits and make things work. Similarly, in all of physics there is nothing as beautiful to me as the simple, principle-based reasoning of the young Einstein while he sorted out the relativities and the quanta, always thinking about knobs and tubes. In Einstein's early prose, there is a clear and luminous reasoning that is never far from the world we can touch. He imagines a man falling from a roof, his tools falling with him—and in that moment he grasps the principle of equivalence. After all these years, I still find the physicality of thought, the abstraction of the material world, utterly captivating.