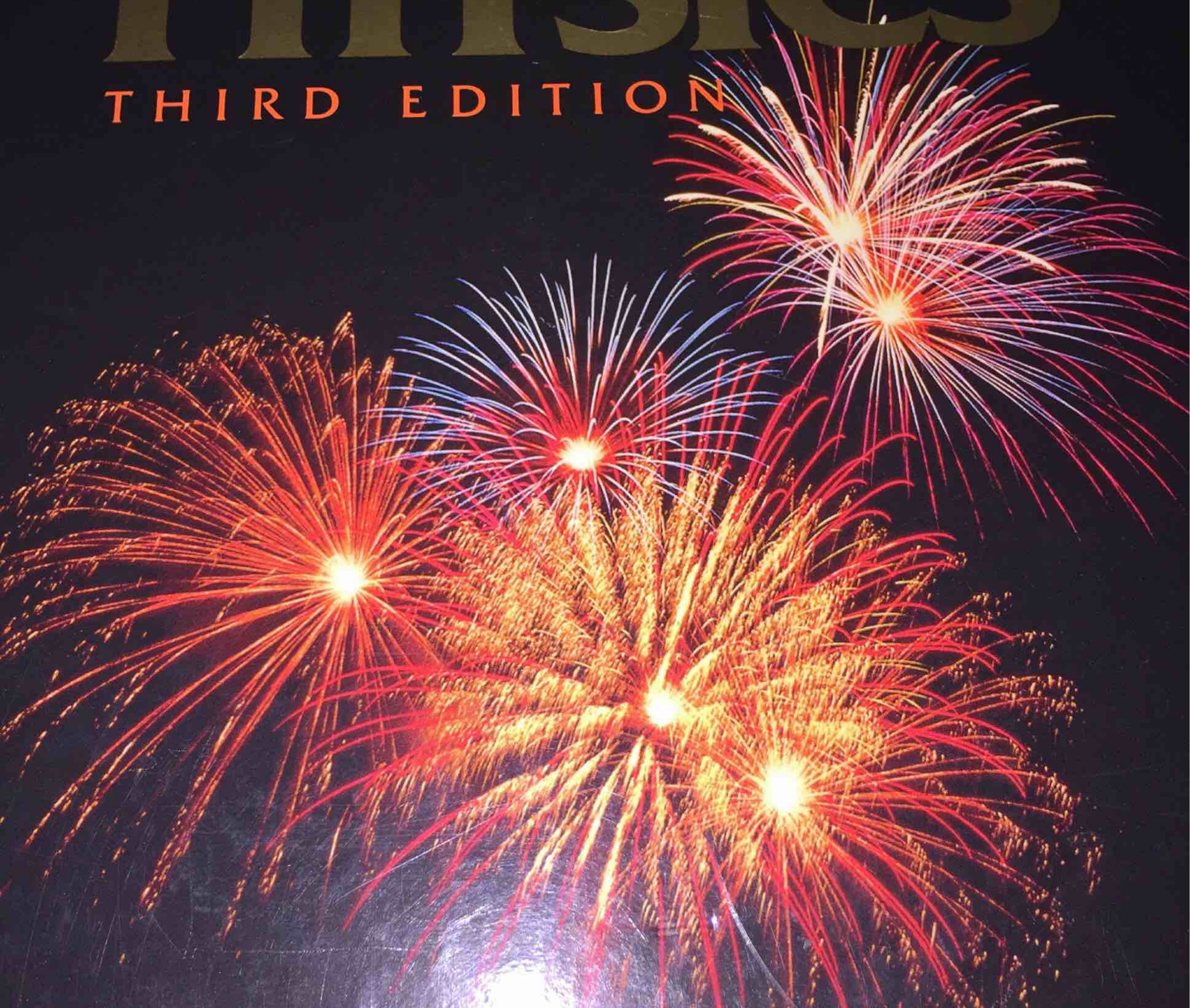
COLLEGE PHYSICS

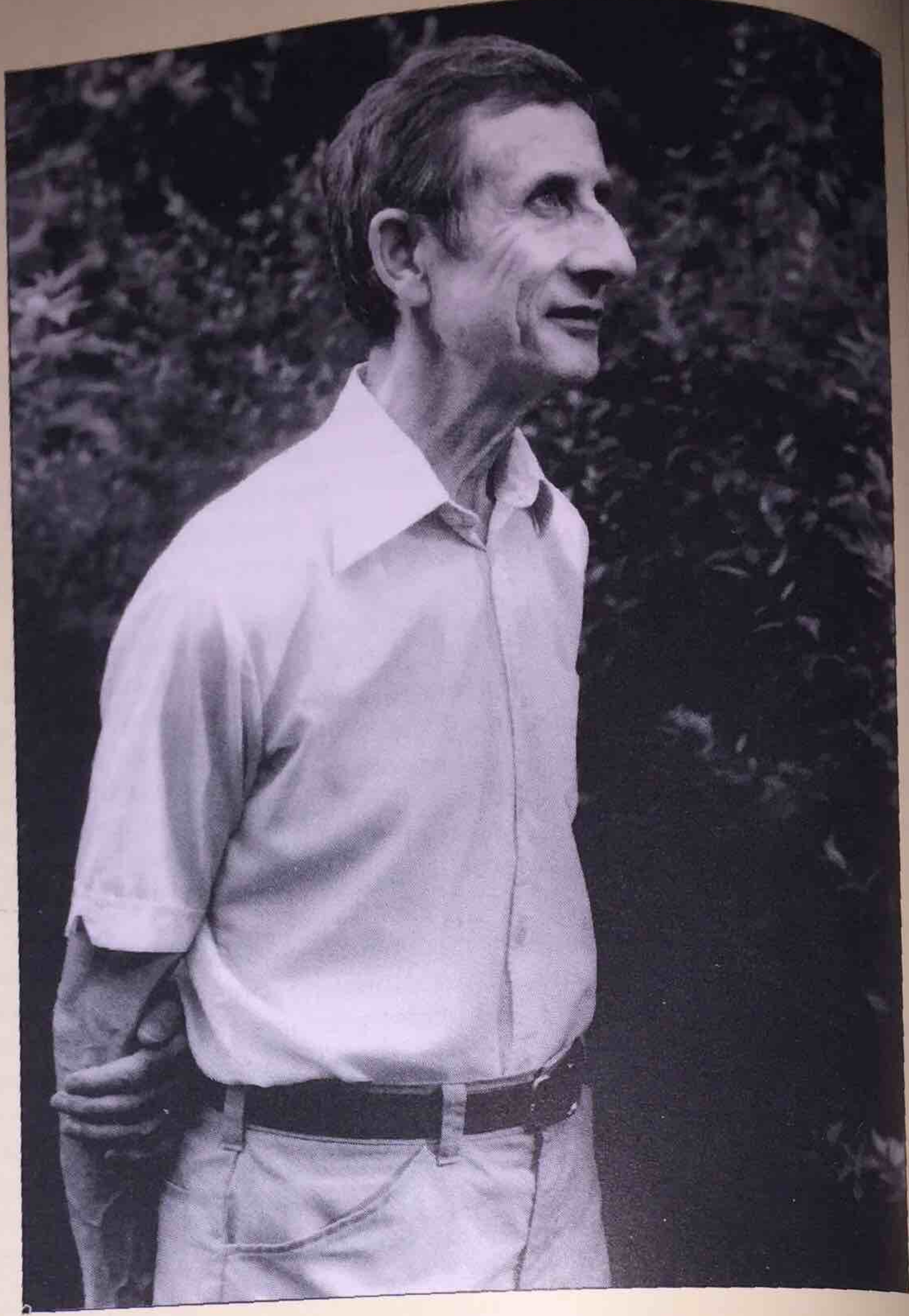
THIRD EDITION



SERWAY & FAUGHN

Conversation with

Freeman J. Dyson



(Courtesy of Mia Dyson)

Freeman Dyson was born in Crowthorne, Berkshire, England, in 1923. He received a B.A. in Mathematics from the University of Cambridge in 1945, studied bombing operations as a professional strategist for the British Air Force from 1943 to 1945, and then taught mathematics at Imperial College in London for a year. Arriving at Cornell University in 1947 with a Commonwealth Fellowship, Freeman Dyson studied theoretical physics with two notable masters of the field, Hans Bethe and Richard Feynman. In the summer of 1948, Dyson achieved recognition for demonstrating the connection between what appeared to be two radically different approaches (one by Julian Schwinger, the other by Feynman) to explaining the breakthrough experiment on hydrogen atoms performed at Columbia University that year. Dyson joined Princeton's Institute for Advanced Study as a visiting member, returned to Cornell as a physics professor, then in 1953 accepted the position of professor of physics at Princeton's Institute for Advanced Study, where he remains today. He has received numerous awards and honorary degrees from around the world in recognition of his contributions to his field.

How did you become interested in science?

Sir Frank Dyson was a leader in international astronomy at the height of his career in the 1930s. He not only held the position of Astronomer Royal but was also President of the International Astronomical Union, and just by pure coincidence he happened to have the same name that I do. He was no relation. He came from the same village as my father, and I heard all about him when I was a kid, so he was a

Interview conducted by Janice K. Mandel.

role model for me. I don't know whether that was the only reason, but it certainly was one of the reasons I got involved in science. I never met Sir Frank.

Can you describe the scientific events taking place as you grew up?

Einstein discovered general relativity, which was his grand new theory of gravitation, in the middle of World War I. One of the main predictions of his theory was that the light from distant stars would be bent as it came around the Sun by a certain angle. It happened that there was a beautiful solar eclipse in 1919, so immediately after the war was over Sir Frank Dyson organized two expeditions to observe the Sun during the total eclipse, which was very important because this was the only time you could do it. Both expeditions were successful. They brought back very good pictures of the stars around the Sun while the eclipse was going on, and Einstein's theory was confirmed. This was an enormously impressive event for the public, and the whole world made a hero of Einstein and, in addition, Sir Frank got a good deal of glory as well.

You recently found a fiction piece you wrote at age 9 among your mother's papers. How does this reflect the times and the impression they made on you?

That is the only document that happens to have survived from my childhood. It was a fragment of a science fiction story about the collision of the asteroid Eros (which comes fairly close to Earth in its orbit every 37 years) and the Moon, which of course was a completely fictional event. Eros did happen to pass by the Earth in 1931, however, which was an important event for professional astronomers—it gave them the most accurate measurement of the distance from the Earth to the Sun, which sets the scale for everything else in the Universe. Sir Frank was organizing the observations by professional astronomers and the analysis of the data. This was in the newspapers and I, no doubt, heard about all this while it was going on. I was 7 years old. The characters in my story were borrowed from Jules Verne, but the leading character, Sir Philip, was no doubt modeled after Sir Frank. Sir Philip was the one who calculated the orbit of Eros and predicted its collision with the Moon.

What was it like to come across this story nearly half a century later?

I was amused to see how little I had changed. I was a writer before I was a scientist, and I was always in love with spaceships. What is striking in this little fragment that I wrote is that I'm describing professional astronomers in the story and they never look at the sky. They're always either out fundraising or sitting at their desks doing calculations. That strikes me 50 years later as remarkably realistic. That was exactly as it was and still is.

How did you choose an area of science for concentration?

I had been interested in physics when I was a kid in high school, and I got sidetracked into mathematics because during the war all the physicists were away working on radar and other such interesting things. So there was no physics being taught, and then I became a pure mathematician more or less because there were still some good pure mathematicians around.

What is a pure mathematician?

A person doing mathematics for its own sake. It's an art form. It is like painting or music: you do it because it's beautiful. It happened that my mathematics teacher in Cambridge was a man called Hardy who was also a rather gifted writer who wrote a famous little book about this subject called *A Mathematician's Apology*, which explains what mathematics means to him. I think it's the best statement about mathematics that has ever been written. He describes what real mathematics is about as opposed to applied mathematics.

What made you decide to turn to physics?

The atomic bomb had been exploded out of the blue sky in August 1945—all the work on nuclear energy had been completely secret. I had been interested in nuclear energy as a possibility, but I'd always thought about it as remote and distant. Smythe, at Princeton at the time, wrote the Smythe Report published on the day that the bombs were announced in 1945. I found it admirable that the United States government published this book explaining roughly what had been done and how and why. To me, that book was a great inspiration. It made it clear that this was a great piece of work and something I should love to be involved with. It wasn't so much that I was interested in building bombs, but interested in understanding how the thing worked. It was obvious that these were really first-rate people who were working on it. So it was reading the Smythe Report that immediately made me switch to physics. Of course, I've always been switching back and forth; I never really gave up mathematics.

You arrived at Cornell in 1947 for a year's study sponsored by a Commonwealth Fellowship and have said that "It was the best possible time for me to be there. Great things were going on." What was happening?

When I came to Cornell in the fall of 1947 there was one tremendous puzzle which everybody was excited about. Some new experiments on hydrogen atoms had been done at Columbia which could not be explained by the existing theories, so it was a real challenge to everybody to try to understand these experiments. So that's what we were working on, particularly Hans Bethe, who was my supervisor at Cornell. He's sort of my spiritual father as far as physics goes. He's a great man and he had produced a very good approximation to a theory of these Columbia experiments, but there were still all sorts of problems with it and so that was the job he gave me to explore.

Can you describe this puzzle in simple terms?

The problem was this: We had a theory of radiation which was developed mostly in Germany around 1930 called Quantum

"Science is better done without a plan. It's all just exploring."

Electrodynamics. That was the standard theory of atoms and radiation, which gave a generally correct description of atoms emitting and absorbing light. It was generally believed to be a correct theory, but it had all kinds of pathologies, what are called *divergences*, which meant if you tried to calculate things accurately it would give you the answer infinity. Nobody understood why the theory seemed to be to first approximation always good, but if you tried to go beyond the first approximation it seemed to be nonsense.

Then came the Columbia experiments led by Willis E. Lamb in 1946 or 1947. These marvelous experiments forced you to go to the next approximation because they were a thousand times more accurate than the prewar experiments. So we had a thousand times more precise experiments of hydrogen spectrum, and so you had to have a better theory in order to explain these experiments.

While searching for a solution, you enjoyed some fame yourself. Would you explain?

During that year at Cornell there were two completely separate new ideas on the problem: one from Schwinger, one from Feynman. They were professors, each only about age 30 at the time. Feynman was at Cornell; Schwinger was at Harvard. Both of them were getting exciting results and better agreement with the Columbia experiments, but what was strange was that these theories were so different. It was very hard to understand either of them precisely, and there was also a problem because neither of them was published and so you had to learn about them by talking to people. So, I was in a very happy position of being friendly with Feynman and also, in the summer following the year at Cornell, I went to the University of Michigan in Ann Arbor and had Schwinger for a six-week lecture series. I was just very lucky to have both of them thrown into my hands.

By August 1948, I'd had enough physics, so I went off on holiday in a Greyhound bus and spent a couple of weeks in Berkeley, mostly just reading in the library and wandering around. After two weeks, in the beginning of September, I took the Greyhound back east, and while I was sitting there on the bus in the middle of the night somewhere in Kansas, suddenly the whole thing came together and Schwinger and Feynman suddenly both made sense and fit together beautifully. That was the big moment I'd been waiting for. As usual, you only get some kind of revelation of this kind if you stop working for a few weeks. After that I became famous very rapidly, because that was the latest fad at the time and people tend to run after the latest fad, so I was in the happy position of being sought after for a year or two.

Are moments of revelation like this one of the rewards of science?

It is something that you can't either work for or manage; you're lucky when it happens. I think the main lesson is that idleness is important. They said Shakespeare was always idle between plays. I think that any sort of really creative work needs idleness. If you're always sitting at the computer terminal, things like this don't happen.

You can't teach talent, but what can you teach others about the creative aspects of discovery?

You've got to have both discipline and freedom. I spent a full year of real hard slogging studying Feynman and Schwinger, which meant sitting at my desk for days and days calculating, making sure I understood the details. That's the discipline you've got to master. But then, you must goof off for a few weeks and let the thing settle down in your subconscious and give it a chance to come up with something new. That seems to be how the thing works: you have to do the hard work first, and then be idle for awhile to give it a chance to turn into something new.

Do you need a particular talent to do theoretical physics? Does it require a background in both math and physics?

You certainly need the talent, but even more than that I suppose you need the drive or whatever it is that forces people to spend long hours doing calculations. You have to enjoy doing calculations, not just be good at it.

How does a theory start? Do you start with an impression, an image, an inspiration? How do you work the process?

For me it comes from writing down equations and trying to solve them. It's not really concerned with images at all. There are a great many different kinds of scientists with different ways of thinking. My way of thinking is mostly just in terms of mathematical symbols. When I'm building structures, they are really systems of equations.

Do you have some end in mind when you begin?

I start with a problem, which means I'm trying to calculate something. For example, at the moment I'm interested in the problem of taking a square array of points, like a chess board, throwing down a circle at random and calculating how many points will lie inside the circle. If things go well, out of it there might come a new way of doing the calculation or there might come a new understanding of the problem; anyway, we'll see. Science is better done without a plan. It's all just exploring. So you get a small step ahead and then you look around and see where you might go next.

You knew Richard Feynman as a young professor at Cornell long before he won a Nobel Prize. Can you describe your association?

I found him absolutely fascinating because he was completely different from everybody else, and he was interested in everything. Sometimes he would be furiously busy and he would just say "Go away!" and not allow you into the room. Then, if he felt like it, he'd go out for a long walk and invite you to come along. So we would go and walk through the hills around Ithaca, and he would tell me the story of his life. I just got to admire him enormously. He struck me as being so unusually sane and, at the same time, in a pleasant way, crazy. It was a very good combination.

Can you tell me about some of those crazier times?

Dick invited me along on a trip to Albuquerque. For me it was just a joy ride. Dick was going there to make up his mind and find out if he was going to marry a girlfriend he had there. His first wife had died of tuberculosis about two years before, and he always said "If you've been happily married once, you can't stay single." I spent three days driving across the country in a car with Feynman, and that was the time I got to know him best. We got caught in a flood, and we had some wonderful nights in sleazy motels where we had the chance to talk about all kinds of things.

Among the things you learned from Feynman, what stands out in your mind?

He had been deeply involved in the Manhattan Project in Los Alamos in 1945 and had an extremely realistic view of the atomic bomb, which I found very helpful. He considered the thing to be unavoidable, a trap we'd fallen into. But he didn't see any good coming of it at all, and as far as he was concerned, he was not going to have anything more to do with it. So for the rest of his life he kept out of it. He didn't regret having been there, but he certainly didn't want to do it again. His view was "You should say yes to everything once and then find out if it's any good. If it turns out not to be any good then say no."

What is your view of science as it relates to weapons?

My viewpoints come from the work I did for the British Bomber Command, which left me deeply scarred. It was not nuclear, but it was a bombing campaign of a very bloody kind. It was indiscriminate bombing of cities on a large scale. I worked on the operations trying to understand how to use the bomber force effectively and particularly how to reduce the heavy bomber losses we were suffering because the German defenses were very good. I got a grandstand view of that whole campaign, and that gave me a burning compulsion for the rest of my life to try to fight the strategic bomber people. To me, it doesn't matter whether bombs are nuclear or not, it's an evil thing and it has a bad effect on people.

"We tinker around and build toys and suddenly they go boom and the whole universe is disturbed. And that's the story of my life in a way . . ."

What is your view of the Strategic Defense Initiative Program (SDI)?

On the whole, I'm in favor of it because I think saving lives by shooting down missiles is a good idea. Unfortunately, the SDI program as it has been run has been a very corrupt kind of an enterprise. I'm not against it on any political grounds, but on technical grounds it doesn't do what it promises. What the Patriot System does very nicely, as we've just seen in the Middle East, is to shoot down missiles when they're coming to a well-defined small area, and not too many at a time. That's a technical problem that we know how to solve. Whereas what the SDI was advertised to do is to defend a huge area against a huge threat, and it never really had the hope of doing that to the extent that was promised. So the program has led to very little that's valuable. Which is unfortunate because I think from the long-range point of view it was not such a bad idea. I would say the best thing to do would be to shut it down and start afresh. Typical SDI activities have been really public relations jobs more than science.

Would you like to discuss a few thoughts on *Disturbing the Universe*, your book that was published in 1979?

The Sloane Foundation, a general charitable trust that supports educational activities, decided to commission a series of autobiographies of scientists. The idea was to give people a sense of what being a scientist is about. Essentially, it is an autobiography but of a very sketchy kind. "Disturbing the Universe" is a phrase taken out of a poem by T. S. Eliot, "The Love Song of J. Alfred Prufrock," where a man is going up the stairs, feeling very shy and wondering whether he should knock on the door where his girlfriend is living, and he comes up the stairs and says "Do I dare, do I dare, do I dare disturb the Universe?" So, that's the theme of the book, that's what we're doing as scientists. It's sort of crazy, but that's the way it works. We tinker around and build toys and suddenly they go boom and the whole Universe is disturbed. And that's the story of my life in a way, at least that's the metaphor.

Conversations With Prominent Scientists

Appearing in each of the text's six parts, the interviews introduce students to individuals who have achieved international recognition in their fields. The conversations cover specialized scientific topics as well as current concerns such as science education and the role of science in society.