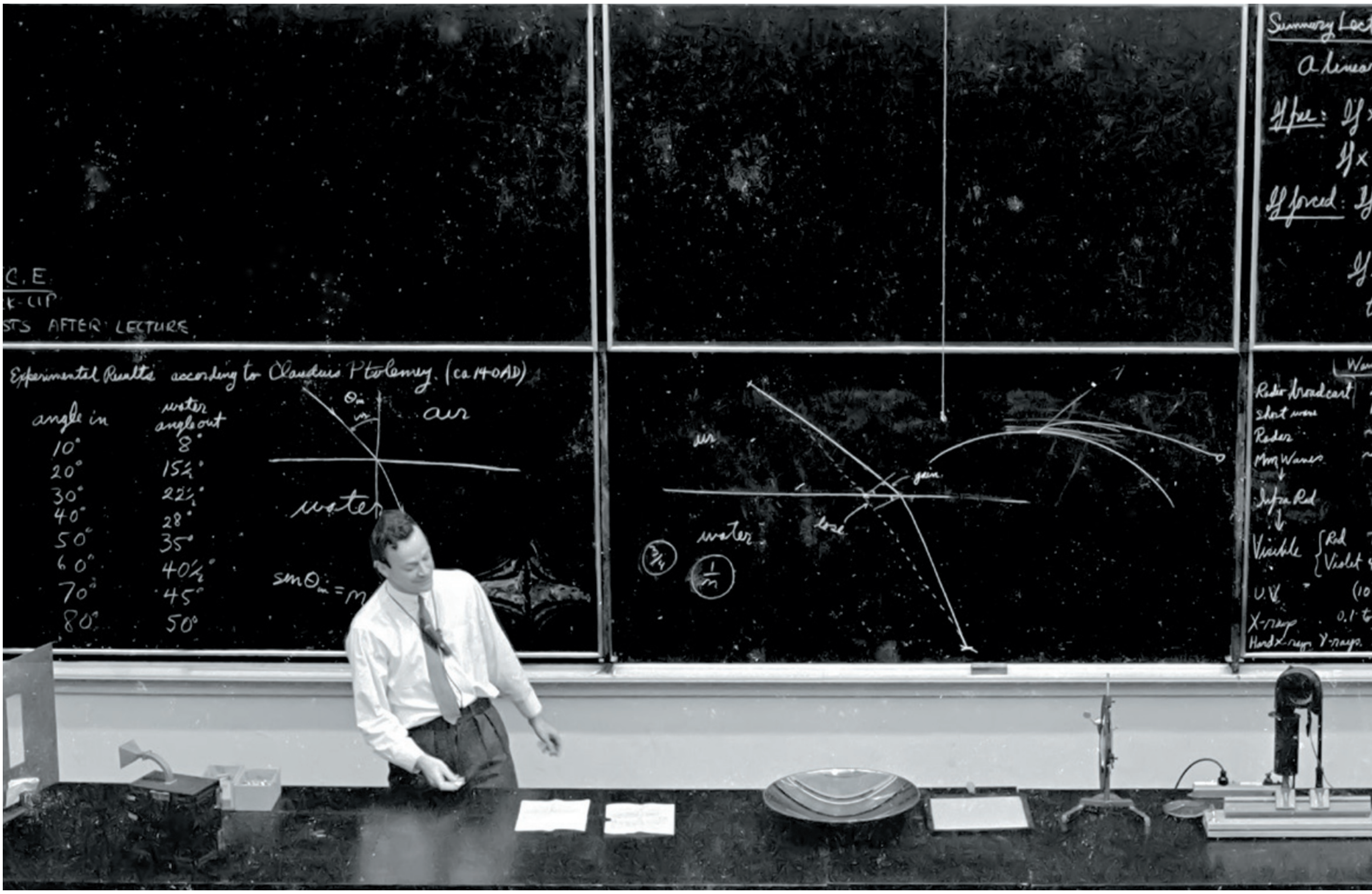


Richard Feynman lecturing in 1962 on optics and Pierre de Fermat's principle of least time.

IN RETROSPECT
The Feynman Lectures on Physics

Rob Phillips celebrates the US physicist's seminal series as it nears its 50th anniversary.

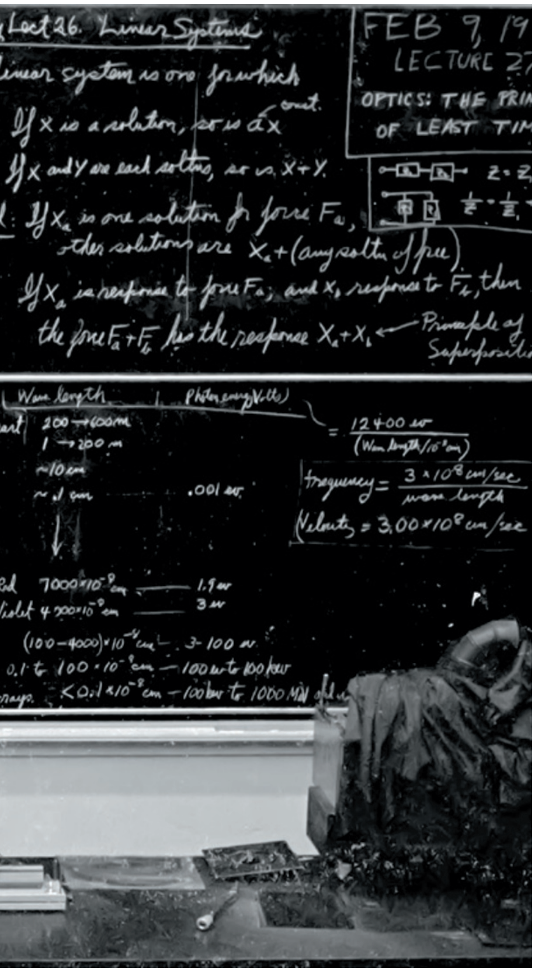
Over the past three decades, I have asked hundreds of people to name the five or ten books that have meant the most to them. Although Jane Austen's *Pride and Prejudice* tops the list, *The Feynman Lectures on Physics* is the science title most often cited. That may say something about the kind of readers I talk to, but it is an accurate reflection of the broad reach of this half-century-old scientific classic.

The book was based on a course the Nobel-prizewinning theoretical physicist and polymath Richard Feynman taught from 1961 to 1963, in an attempt to reinvigorate 'freshman physics' at the California Institute of Technology (Caltech) in Pasadena. In 1964, the course was published as the three-volume *The Feynman Lectures on Physics*, by Feynman and fellow physicists Matthew Sands and Robert Leighton. With his lectures, Feynman joined a long tradition of famed physicists — such as Max Planck, Arnold Sommerfeld, Wolfgang Pauli and Lev Landau — providing personal grand vistas. Unlike those, Feynman's vista is 'elementary' and joyous — a joy deeply magnified in the audio version.

What makes these lectures timeless? Elementary physics has been taught to undergraduates for nearly a century with relatively little change. Over the past 50 years the subject has been even more static. Textbooks and introductory courses have largely targeted those planning to study medicine and engineers with a focus on formulaic problem-solving and exam preparation, rather than cultivating a wonder for nature and the development of physical intuition.

Superficially, Feynman's primer touches on the same topics that others do: mechanics, thermodynamics, optics, electricity and magnetism, and modern physics. Beneath this veneer of common cause, his introduction to elementary physics seems to have higher aspirations — the love of nature and a grasp of it through experimentation and reasoning. In Feynman's hands, even a topic as mundane as projectile motion becomes the story of how Galileo and Newton unlocked the secrets of planetary motion. Feynman's physics is about simplicity, beauty, unity and analogy, presented with enthusiasm and insight that bursts from the page.

He works this magic even in areas often thought to be the most boring parts of the curriculum. For example, his fascination with the way that Newton's second law of



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motion, $F = ma$, can describe the motions of large, composite objects such as galaxies leads intuitively to the profound idea of the centre of mass. Feynman also repeatedly appeals to 'variational' principles based on minimizing quantities such as travel time (pictured). This is seen nowhere more impressively than in the way he develops optics by thinking about the transit of light rays as they pass through various media, whether lenses or the atmosphere. These same ideas return in his treatment of the elliptical motions of planets. When talking about Brownian motion (the random movement of particles in a gas or liquid as they collide with molecules of that medium), he elegantly teaches us the fluctuation–dissipation theorem, which relates how rapidly particles diffuse to the drag force they experience, without ever naming it as such. And he similarly provides an advanced but accessible introduction to elasticity — the likes of which, unfortunately, advanced physics students rarely see even now.

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Daniel Cressey on the art of the Feynman diagram:
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In a handful of pages on electrostatic analogs and the unity of nature, Feynman points out how many different phenomena can all be approached using the same underlying mathematics — the electrical potential around charged objects, heat flow between plates held at different temperatures, the vibrations of a drumhead, the diffusion of neutrons and the flow of a fluid past a sphere. Such unity is further revealed by his potpourri of examples of resonance in nature. These range from the 'oscillator' of Earth's atmosphere as it sloshes back and forth, driven by the Moon, to the Mössbauer effect revealed when atomic nuclei absorb high-frequency radiation.

Feynman seems to be teaching the idea that there is no one right way to view a problem. As he put it in his 1965 Nobel lecture, "Theories of the known, which are described by different physical ideas may be equivalent in all their predictions and are hence scientifically indistinguishable. However, they are not psychologically identical when trying to move from that base into the unknown … I, therefore, think that a good theoretical physicist today might find it useful to have a wide range of physical viewpoints and mathematical expressions of the same theory."

One of the most delightful features of the *Lectures* is that Feynman is constantly on the lookout for physics writ large. From lightning to the periodic table and the energy levels of chlorophyll, he is not interested in naming conventions that separate different academic disciplines. How many physics books have a section entitled "More organic chemistry"? In it, he shows us how to use simple quantum-mechanical models to work out the spectrum of energy levels of different types of molecules. Chapters 35 and 36 of Volume 1 take on topics related to vision, such as the anatomy of rod cells, how the molecule retinal in photoreceptor cells works, the resolution of the compound eye of the bee and the mysteries of colour vision — reflecting his 1960s adventures in biology. Feynman would relate these in more detail in *Surely You're Joking, Mr. Feynman! Adventures of a Curious Character* (W.W. Norton, 1985), his book of reminiscences based on taped conversations with Ralph Leighton, the son of his *Lectures* co-author Robert.

BREAKING THE MOULD

The breadth of Feynman's scientific interests was brought home to me during a chance visit to the Caltech archives. Accompanying a colleague who wanted to examine the papers of Max Delbrück, I noticed two boxes of papers open on a desk. They turned out to be Feynman's. Randomly flicking through, I was struck by nearly 100 pages of notes from the 1960s with a peculiar, decade-long timeline marked in Feynman's unmistakable writing. For March 1966, he had written "Footprints of Tumor Viruses, The Nerve Axon". For April 1966, "Sex differences in the brain, Chromosome analysis by computer, antibiotics & the genetic code". As I guessed and later confirmed, these were all topics he was reading about in *Scientific American*.

Feynman seems to have been hard at work learning anything and everything he could about biology, coloured by physical reasoning — although by then he was one of the most famous physicists in the world. Page after page is littered with Feynman's drawings, notes and questions on topics ranging from the phylogeny of plants and animals, and the structure of proteins to the beautiful membrane structures of mitochondria. They give a feeling of his roving mind busily formulating his own version of biology. More importantly, they show once again his delight in learning about the marvels of nature and his urge to bring order to the things he knew. At the end of these notes, Feynman returns to the mysteries of the quantum world — his biological musings are replaced by lengthy calculations.

"Feynman's physics is about simplicity, beauty, unity and analogy, presented with enthusiasm and insight."

Mark Twain quipped that a classic is something that everybody wants to have read and nobody wants to read. Feynman's classic breaks the mould. Some respondents to my 'favourite books' query speak of dog-eared copies lovingly read on long stints around the globe. Among them are a young high-school student who in Yugoslavia's Communist era tried to master Maxwell's equations; an Israeli army officer stealing time to read every page over years of duty; and a brilliant Indian undergraduate trying to breathe life into a freshman physics course designed to 'train' engineers. One travel-bum mathematics student decided it was time to learn physics — and turned to the lectures, eventually landing a place as a graduate student in Feynman's former department at Caltech. The book has a cult following among non-specialist readers as well.

As Feynman writes in his epilogue to the series: "I most wanted to give you some appreciation of the wonderful world and the physicist's way of looking at it … it is even possible that you may want to join in the greatest adventure that the human mind has ever begun." It is because they serve as an expert and loving guide to this great adventure that *The Feynman Lectures on Physics* are as timely now as they have ever been. ■

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The New Millennium Edition of the *Lectures* is available from Basic Books. The series is free at www.feynmanlectures.caltech.edu.