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Negotiating the peaks and crevasses of the strange world of special relativity is akin to scaling the Matterhorn.

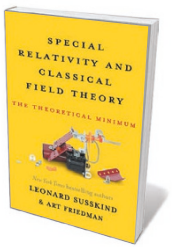
RELATIVITY

A steep ascent of physics

Robert P. Crease applauds the third volume of a thrilling guide to a special pursuit.

Since 2007, physicist Leonard Susskind has regularly delivered a lecture series called the Theoretical Minimum, on the foundations needed to study different areas of physics (http://theoreticalminimum.com/home). Companion volumes have emerged, the first on classical mechanics and the second on quantum mechanics. *Special Relativity and Classical Field Theory* is the third volume. Like the book on quantum mechanics, it is co-authored by Art Friedman and aimed, in Susskind's words, at "physics enthusiasts" or "people who know, or once knew, a bit of algebra and calculus, but are more or less beginners".

The latest volume concerns the strange world that Albert Einstein discovered by combining James Clerk Maxwell's field theory with Isaac Newton's mechanics — a world in which moving fast makes time compress and lengths shorten. To understand it, challenging mathematical tools are required. In this volume, as in the others, you get the sense of being led up a legendary mountain by a trained guide. The guide knows you are an amateur, but wants you to get to the top on your own, without being airlifted over risky terrain. You do not hike through some of the hardest passes or peaks, nor past some of the most magnificent vistas. It's a peculiar route, and you encounter many sites in a different order from the one early explorers adopted, or from how experts are used to teaching. But it's accessible. And you do get to the top. As an amateur myself, I found it thrilling.



Special Relativity and Classical Field Theory: The Theoretical Minimum
LEONARD SUSSKIND AND ART FRIEDMAN
Basic: 2017.

The path starts with the first lecture, a discussion of reference frames. These are tools for labelling the positions of objects in your immediate space, and in spaces moving with respect to yours (such as on a train), that allow you to go back and forth between the spaces. Understanding them is an important skill for traversing rough spots ahead. Other essential tools include space-time, in which the reference frame includes time as well as space; proper time; and four-vectors, special kinds of paths and objects in space-time.

In a book on special relativity, you might expect to meet Einstein's mass–energy equivalence, $E=mc^2$, close to the beginning. Yet you don't encounter it until Lecture 3, about 100 pages in, where it is refreshingly derived from first principles. You don't get the important Euler–Lagrange equation, which describes particle motion, until Lecture 4. Poisson's equation, for the electrostatic potential of a particle, and the Klein–Gordon equation, which describes a particle as a wave and relativistically, don't show up until Lecture 5. Gauge invariance, the basis of modern field theory, appears first in Lecture 7; Maxwell's equations, which provide the foundation of classical electromagnetism, materialize in Lecture 8; and the Poynting vector, which describes the flow of energy in electromagnetic waves, surfaces first in Lecture 11.

From a historian's point of view, therefore, the path is topsy-turvy. But Susskind's approach is to subject the novice to an ahistorical mathematical boot camp to make the path seem natural, and ultimately easier.

He appeals to the reader's evolving understanding to stay motivated, rather than airing his own expertise. Whenever you are puzzled by the famous conundrums of special relativity — the twin paradox, for instance, in which a sibling journeying on a light-speed ▶

rocket ages less than one who stays at home — he instructs you to "draw a space-time diagram". Such visual representations, he notes, make most of the weirdness in relativistic events go away.

Friedman pops up as the most vocal hiker on this at-times steep slope. He is not averse to making protests: "I don't recognize any of this. I thought you said we were going to get the Lorentz force law." ("Lenny" replies: "Hang on, Art, we're getting there.") Such jousts are infrequent, yet preserve the book's informal tone. In that vein, the narrative is rich in remarks at once witty and insightful. Modifying physicist John Wheeler's quote on relativity — "space-time tells matter how to move; matter tells space-time how to curve" — Susskind remarks, "Fields tell charges how to move; charges tell fields how to vary."

Understanding the theoretical minimum in special relativity and classical field theory, however, itself demands a certain minimum of preparation and research. The book occasionally bumps up against this problem, referring the reader to earlier volumes; or Susskind might impatiently write, "If you don't know what a cross product is, please take the time to learn."

The last few chapters are the steepest. You meet landmarks that would have been encountered much earlier in a historical approach, such as the laws of Maxwell, Charles de Coulomb, André-Marie Ampère and Michael Faraday — and even Maxwell's discovery that light is composed of electromagnetic waves, not mentioned until close to the end. But these conclusions fall right out of the tools you have been given in your intensive training — which Susskind calls the "cold shower" approach.

So why buy the book when the lectures are online? The online course consists of ten lectures, each anywhere up to two hours long, whereas the book is orderly and concise. You can go at your own pace, make notes and appreciate where Friedman — a former student of the course — becomes your stand-in and asks the questions that nag at you. You can refer back to something you read earlier and locate it quickly, rather than try to remember how far into the lecture it was and skip around until you find it. Finishing the book, you the physics enthusiast may not have a more profound view of any particular landmark in physics than before. But you will surely have a much more reliable map of the territory. ■

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Sherlock Holmes applies his chemical skills in this 1893 illustration by Sidney Paget.

AF FOTOGRAFIE/ALAMY

FICTION

The science in Sherlock Holmes

Maria Konnikova detects the fictional sleuth's inner researcher, 130 years on from his 'birth'.

It's perhaps the most famous encounter in an oeuvre filled with them.

"You have been in Afghanistan, I perceive."
"How on earth did you know that?" I asked in astonishment.

When Sherlock Holmes first meets Dr John Watson, he identifies the physician's background at a glance. To many, that moment in Arthur Conan Doyle's *A Study in Scarlet* (1887) — Holmes's debut — is a smile-worthy flight of fancy. Except it isn't entirely fantastical. One of Conan Doyle's mentors at the University of Edinburgh, UK, where he trained as an ophthalmologist, was the surgeon Joseph Bell. And it's to him that we owe the famed exchange about Afghanistan, as well as much of Holmes's character.

Bell's accuracy in diagnosis is well documented, and was so renowned that he served as Queen Victoria's personal surgeon when she visited Scotland. Central to this

ability were his powers of observation. It was while working as Bell's ward assistant that Conan Doyle witnessed the doctor correctly identifying the former profession of a retired army officer, as well as where he had served — Barbados. "The student must be taught to observe," Bell asserted. A patient would believe in the doctor's curative prowess "if he sees that you, at a glance, know much of his past". It was a message that burrowed into the young Conan Doyle's mind. As he wrote to Bell years later, "Round the centre of deduction and inference and observation which I have heard you inculcate, I have tried to build up a man who pushed the thing as far as it would go — further occasionally."

RENAISSANCE MAN

Holmes, of course, is more than a diagnostician. He is a chemist, psychologist, logician, inventor: all faces that filled Conan Doyle's pre-Holmesian life. In that era of profound scientific change, apparently improbable ideas — such as evolution and the existence of electromagnetic waves — were suddenly central to the conversation. Having rejected his early Jesuit education for Darwinism and empiricism, Conan Doyle himself was close to the ongoing revolution.

At Edinburgh, he encountered many of the thinkers at the forefront of innovation. The surgeon and pioneer of antiseptic medicine Joseph Lister exposed him to Louis Pasteur's work on germ theory. Conan Doyle became fascinated with the possibilities opening to medicine — a fascination that Holmes would take to fictional heights. In *A Study in Scarlet*, for instance, Holmes exclaims, "I have found a reagent which is precipitated by haemoglobin, and by nothing else." The fiction predated the science: German bacteriologist Paul Uhlenhuth discovered the precipitin test for human blood only in 1900.

Conan Doyle also encountered the analytical toxicologist Robert Christison, an expert witness in numerous criminal cases — and an inspiration for Holmes's expertise in poisons. It may have been through his interest in forensic science that Conan Doyle was exposed to another innovator: Alphonse Bertillon, a pioneer of anthropometrics, in which personal measurement is used to identify criminals (fingerprinting owes its existence to his work). Wherever the exposure happened, it stuck. In *The Hound of the Baskervilles* (1902), we learn that Holmes was considered only the "second highest expert in Europe" on anthropometrics, after Bertillon. (Holmes begs to differ.) Medical training, Conan Doyle believed, fostered a "healthy scepticism" and reliance on facts: the "finest foundations for all thought". Certainly, Holmes is the greatest of healthy sceptics.

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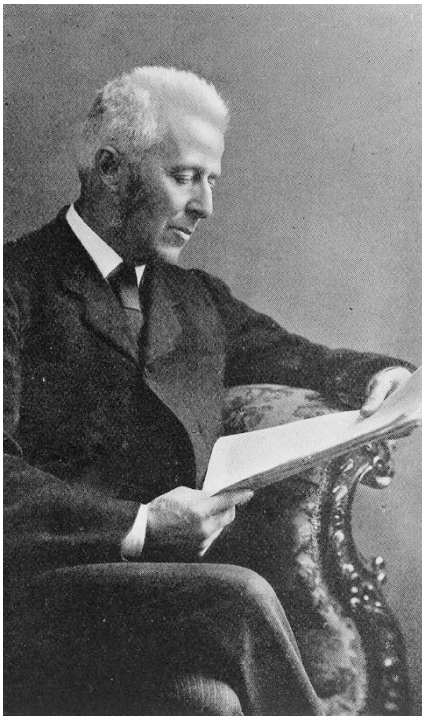

Surgeon Joseph Bell's acute powers of observation proved an inspiration for Arthur Conan Doyle.

Intentionally or not, Holmes also emerged as a scientific ambassador to the masses. Conan Doyle references Lister's use of carbolic acid for antisepsis in the 1892 story 'The Adventure of the Engineer's Thumb', when Watson uses it while dressing a wound. Before Sigmund Freud became a household name, Holmes was homing in on hidden desires and impulses, although he based his conclusions on decidedly more objective criteria. He muses, for instance, on what would drive a trainer to harm his own horse, a key insight in the 1892 'Silver Blaze'. (Conan Doyle had read Freud's early writings, as well as his 1884 paper 'Über coca', which touted the benefits of Holmes's drug of choice, cocaine.)

HOLMES'S HEAD

It is perhaps as psychologist that Holmes's contribution to popular science is most evident. Take George Miller's 1956 paper 'The magical number seven, plus or minus two', which posits that humans can cognitively process only around seven pieces of information at any time. It seems to me no coincidence that Miller used an image of a cutaway head with an attic instead of a brain — a probable echo of Holmes's conceptualization of memory in *A Study in Scarlet*. The brain is originally, Holmes says, like "a little empty attic"; but because it lacks "elastic walls", the "skilful workman is very careful indeed" about what he takes into it.

Holmes's espousal of mindfulness came more than a century before the concept became ubiquitous. Consider his approach to solving a crime: contemplate first, eyes closed, fingers cradled. A passage in the 1891 story 'The Red-Headed League' is a key example. As Watson asks Holmes's opinion of the case, Holmes intones: "It is quite a three-pipe problem, and I beg you won't speak to me for fifty minutes." What is this but directed meditation? Holmes takes contemplation to a new level, with unilateral focus and no distractions. We even learn that the detective studied with the "head Llama" in Tibet during the Great Hiatus, the period after his supposed murder by Professor Moriarty — another scientist, possibly based on the brilliant but spiteful astronomer Simon Newcomb.

Equally telling is Holmes's detailed exploration of biased decision-making and the clash between cool-headed choices and hot emotion. As he explains to Watson in *The Sign of Four* (1890), "A client is to me a mere unit, a factor in a problem. The emotional qualities are antagonistic to clear reasoning", adding that "the most repellent man of my acquaintance is a philanthropist who has spent nearly a quarter of a million upon the London poor". Emotion is responsible for many of the biases in decision-making explored by psychologists such as Daniel Kahneman, in his *Thinking, Fast and Slow* (Farrar, Straus and Giroux, 2011).

"Holmes is the greatest of healthy sceptics."

Holmes is a continually reinterpreted cultural icon. Conan Doyle's 1892 short-story collection *The Adventures of Sherlock Holmes* alone has sold in the tens of millions. We cannot get enough of him — and that, I think, is a good thing. As a champion of observation and a personification of rationality, Holmes seems more relevant than ever in a world marked by science denialism and over-emotionality. "You know my methods. Apply them," the detective tells Watson in *The Sign of Four*. It's high time we did just that. ■

Maria Konnikova *is the author of* The Confidence Game *and* Mastermind: How To Think Like Sherlock Holmes. *Her next book,* The Biggest Bluff, *explores the balance of skill and chance through a year-long immersion in the world of high-stakes poker. She is a contributing writer for* The New Yorker *and host of podcast 'The Grift'. e-mail: maria_konnikova@newyorker.com Twitter: @mkonnikova*

CORRECTION

The Books & Arts article 'Final ascent of physics' (*Nature* **549,** 331–332; 2017) incorrectly stated that *Special Relativity and Classical Field Theory* is the last book in the Theoretical Minimum series, and described it as "historical" instead of "ahistorical". The text and title have been corrected.