

1 “Superfluous”: The Stories of Einstein’s Special Relativity

Chapter outline
4 October 2022
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1.1 We’re all Greek – The Presocratics

Primary profiles of: Thales and Ionian friends, Pythagoreans, Heraclitus, Parmenides, Democritus.

Secondary profiles of: Empedocles and Anaxagoras.

The Science: Asking “how” things worked, envisioning the substance of things and existence, and promoting mathematics from just counting to the concept of number and existence.

You can only invent something for the first time, once. Starting in the sixth century BCE, science was invented. Well, nearly. There was something about Greeks who lived on the bustling western shores of modern Turkey and the instep of the boot of Italy where after at least two millennia of sophisticated ancient civilizations, people started to think about their universe differently from all who came before.

1.2 Can’t Live With ‘Em Or Without ‘Em – Plato, Aristotle, and Greek Astronomy

Primary profiles of: Thales and Ionian friends, Pythagoreans, Heraclitus, Parmenides, Democritus.

Secondary profiles of: Empedocles and Anaxagoras.

The Science:

Whitehead once noted that all of philosophy consists of footnotes to Plato. While pithy and almost too simple sounding, it’s pretty much on target. I’m in a sub-discipline of physics that’s totally Platonic. But also Aristotelian! Such is our confusing relationship with the Greeks. We’ll explore the habits of mind that primarily Plato and Aristotle endowed us with, simultaneously rolling our eyes at their silliness while being captured by their persuasiveness. Of course, Ptolemy’s epicyclic calculational model of the solar system was Greek and it took a thousand years to move beyond it. Can’t live with the ancient Greeks, can’t live without them.

1.3 Not So Dark After All – The Medievals

Primary profiles of: Nicholas Oresme, The Merton School,

Secondary profiles of: Averroes , William Heytesbury, Roger Bacon, Thomas Aquinas

The Science: Rediscovery of Greek philosophy, Aristotle in particular, early thoughts of local and relative motion which influenced Galileo.

We're all taught that the Medieval period was dark. No intellectual light. Stagnant and, well, just stuck. But that's not accurate. Reconciliation between the Church and Aristotle unleashed critical thinking and professors and students in Paris and Oxford laid out a pattern of reasoning that inspired Galileo and Descartes. Very early, the idea of a “graph” and ideas about falling bodies—and even relativity were all discussed in the 14th century. Everyone knew that Aristotle's model of unnatural motion was flawed.

1.4 Almost the Renaissance Man – Nicolaus Copernicus

Primary profiles of: Nicolaus Copernicus

The Science: Planetary motion and early concerns for motion of the earth.

One book. That and a pamphlet were his total printed output and it's poignant that he reportedly only held “that book” in his hands on his deathbed. So ill was he, that he probably didn't notice the scandal that was its preface. . . a part of the book that he didn't write. There's much that is misunderstood about Copernicus' work, but there's no doubting his influence in astronomy, but also mathematics. That book is a dense treatise on spherical geometry. He was a boundary character with one foot in the Renaissance and another foot pointing at the Baroque. Given the support he enjoyed from the Church during his lifetime he would have been surprised at how his work became a target later.

1.5 A Marriage Not Made in Heaven – Tycho Brahe and Johannes Kepler

Primary profiles of: Tycho Brahe, Johannes Kepler

The Science: The beginnings of quantitative, precise astronomy, the shattering of the crystalline spheres and a unchanging heaven, quantitative astrophysics, use of logarithms and decimals, the first notions of a force between the sun and planets, and the first quantitative model of motions around the sun.

It's easy to put Tycho Brahe in a category of crank. There's the fake nose that refused to stay glued to his face and of course his pet moose who died while trying to descend the stairs while drunk. But he was the first modern experimental scientist and national laboratory director. While Johannes Kepler was the sorriest character in the history of physics, he was the first to break out of a 2000 year reliance on circles—because the data forced him to. Data he

stole from Brahe's heirs. The intellectually bravest individual in the history of physics. Together, those two were a hot mess.

1.6 Doctor to the Queen – William Gilbert

Primary profiles of: William Gilbert

Secondary profiles of: Francis Bacon

The Science: Inductive analysis, among the first experimental methods, magnetism, magnetism of the earth.

Want to know where you are? Look at the compass which you know tells you where the magnetic south pole of the earth is (it's in the north). Why? How? Well, that recognition came from first Queen Elizabeth's physician and arguably one of our first modern-looking experimental physicists. A theorist and a modeler, contemporary of Galileo, Bruno, Shakespeare, and Francis Bacon.

1.7 The Man With Two First Names – Galileo Galilei

Primary profiles of: Galileo Galilei

Secondary profiles of: Girolamo Borro, Vincenzo Galilei, Thomas Harriot, Guidobaldo del Monte, Christoph Scheiner, Robert Bellarmine, Orazio Grassi, Grand Duchess Christina of Florence, Maffeo Barberini (Urban VIII), Marin Mersenne, the Wachowskis

The Science: Motion, acceleration, the pendulum, telescopes, scientific method, Platonism, and a completely incorrect—but critical to Galileo—model of the tides.

Remember Johnny Cash's song, *A Boy Named Sue*, about the the unfortunate naming that forged in the son his "gravel in his gut and the spit in the eye"? Galileo Galilei inherited that level of challenge from his father. Expected to do great things as that physician of note, a famous relative of 150 years previous and respected Florentine namesake. Instead, Galileo #2 dropped out of medical training and changed the world. Bitter pill to swallow for his dad. But we treat Galileo as the father of physics for his experimentation, but not always appreciated, also for his Platonism. Of course his astronomy was ground-breaking, but it's not realized that many of his discoveries were not his alone, nor even his first. Telescopes were a hot item in the Netherlands, Britain, and Rome with other smart natural scientists. Another debt we owe to him is his first enunciation of a very modern way of looking at the relationship between authority and science, arguably taking the Church's truce with Aristotle in a new direction. Finally, his enunciation of "Galilean relativity" turned out to be only half the story that Einstein fully fleshed out.

1.8 His Own Axes – René Descartes

Primary profiles of: René Descartes

Secondary profiles of: Isaac Beeckman, Pierre Gassendi

The Science: Mathematics, mechanism, motion, collisions, and the deductive method.

The Father of Western Philosophy moonlighted as maybe the Uncle of Theoretical Physics. While inventing analytic mathematics. It's perhaps trivial to emphasize the top-down versus bottom-up approach to scientific behavior, but there's much to be gained by contrasting the deductive instincts of Descartes with the more nuanced Newtonian "if it works" approach of modern times. In needing to point out that he "feigned no hypotheses" Newton hinted that he believed Descartes' influence was to be contended with. Descartes is an enigma in some ways: his description of collisions? Wrong. But his explanation of the rainbow? Inspired. His model of the solar system? Tortured. But his mathematical approach to describing nature? Among the first.

1.9 From Lenses to Collisions on the Canal – Christiaan Huygens

Primary profiles of: Christiaan Huygens

Secondary profiles of: Robert Boyle, Rembrandt

The Science: Collisions, algebra, pendulum, astronomy, calculus, and centripetal force.

When he got up in the morning as a child, he might have found Descartes at the table, or perhaps Rembrandt. His father was a diplomat and creative person—knighted in both Britain and France and was a correspondent of Galileo's. So, an unusual house. Christiaan was no less a man of many talents and enjoyed international fame similar to that of his father. For example, he was elected member of both the Royal Society of London and the French Academy of Sciences. From grinding better lenses than anyone, to using the resulting telescopes to reveal the Saturn that confused Galileo, to the mathematics of circular motion and collisions, as well as hinting at mathematical infinitesimals, to the practicalities of inventing the Grandfather Clock, Huygens was unique—one of the few colleagues truly admired by the notoriously difficult Isaac Newton.

1.10 The Lion – Isaac Newton

Primary profiles of: Isaac Newton

Secondary profiles of: Robert Hooke, John Locke, Gottfried Wilhelm Leibniz, John Flamsteed

The Science: Mechanics, force, momentum, circular dynamics, gravitation, calculus, binomial theorem, and a new scientific strategy.

“Genius” is thrown around too much, but in our story we’ll come across a handful of people who fit anyone’s image of genius. Newton is perhaps our first. Descartes was a mechanist: meaning he believed that matter’s mechanical interactions caused all motion. Nothing spiritual, nothing occult, nothing random. God originally inserted overall motion into the universe, and apparently then abandoned his creation in order to pursue other interests? At first, Newton gravitated (sorry) toward Descartes. . . inspired by his new approach, reading him outside of school. But he began to sour. Descartes was all about *Why*. Newton learned to migrate from *Why* to *How*. That was new and not altogether welcome—but it worked! His description of motion on the earth and motion in the heavens and the connection between them solidified his place in history, without ever ascribing the direct cause of especially gravity. And, of course when your mathematical toolbox is insufficient, you invent calculus.

1.11 The Last Man Who Knew Everything – Thomas Young

Primary profiles of: Thomas Young, François Arago, Augustin-Jean Fresnel, Hippolyte Fizeau **Secondary profiles of:** Léon Foucault

The Science: The debate about light as a wave or as a Newtonian particle.

As a teenager, he became fluent in Greek and Latin and as an adult, he completely deciphered the Rosetta Stone. Along the way, he showed that light was a wave (Double Slit Experiment), that materials could be characterized by their stiffness (Young’s Modulus), pioneered the study of color vision, and characterized capillary action mathematically (Young–Laplace equation). And introduced the ether into physics. . . all while practicing as an active physician. His breadth was enormous and in our story, while he endured scorn by the British Newtonians, he is remembered as the one who indisputably showed light to be a wave.

1.12 The First and Last of His Kind – Michael Faraday

Primary profiles of: Michael Faraday, Humphry Davy **Secondary profiles of:** Hans Christian Ørsted, André-Marie Ampère

The Science: Magnetism, Induction, electrochemistry, public scientific outreach, lines of force, and fields.

Right out of Dickens, is the Faraday story. In fact, he and Dickens were friends. “Self-made man” seems a label designed for Michael Faraday and there will never be another of him. Mathematically illiterate, he nonetheless thought like a mathematician and without the British indoctrination of Newtonian ideas from the schooling that he never had, he used that intuition to postulate the absurd: the field. His experiments won him international fame and his discoveries in electricity, magnetism, and chemistry created our modern conveniences. But

also his devotion to public demonstration and explanation substituted for the academic teaching life that he never had, but as a consequence he probably inspired more non-specialists in science than any professorial job ever could.

1.13 The Inventor of Modern Physics – James Clerk Maxwell

Primary profiles of: James Clerk Maxwell

Secondary profiles of: Daniel Bernoulli

The Science: Electric and magnetic fields and molecular motion.

Dafty. That was his nickname as a kid at the Edinburgh Academy when he entered at the age of 10. The name didn't match the boy: by the age of 14 James Clerk Maxwell published his first mathematical paper. His subjects were broad... from explaining color vision, to solving the mysteries of Saturn's rings, to working out the mechanical explanation of gasses and heat. All enough to have solidified his reputation. But he also mathematical gave life to Faraday's intuitive "picture" of the fields surrounding magnets, currents, and charges. "Maxwell's Equations" bedevil engineering and physics students today, but they predicted electromagnetic waves that travel at the speed of light and therein lies an important, nuanced story for relativity. Said Einstein, "[his work was the] most profound and the most fruitful that physics has experienced since the time of Newton." But Maxwell needed the ether!

1.14 The Brewer – James Prescott Joule

Primary profiles of: James Prescott Joule

Secondary profiles of: John Dalton, Julius Robert von Mayer, Hermann von Helmholtz

The science: The mechanical and electrical equivalent of heat and kinetic energy, including Helmholtz's model.

Brewing beer requires controlled heat and doing at industrial scale is expensive in energy. If your business is beer, then efficiency and temperature control are your concerns. If in the process, you manage to destroy the prevailing view of the nature of heat, unravel its mechanical equivalent, and invent the concept of energy? All the better. James Joule demonstrated to tough crowds in the engineering-oriented Manchester and London that heat and motion are both forms of energy which can be converted back and forth—and not disappear. skepticism gave way to respect so much so that in the year that Joule died, the *Joule* was designated as the internationally-used unit of energy. Even in the not-centigrade, not-meter, not-kilogram United States, we pay our electricity bills according to Watts, which is Joules/second of energy used.

1.15 The Most Important Zero Ever – Albert Michelson

Primary profiles of: Albert Michelson

Secondary profiles of: Hermann von Helmholtz, Hippolyte Fizeau, Ole Christensen Rømer, Edward W. Morley

The Science: Virtuosity in experimental optics, Michelson Interferometer, speed of light measurements, and the ether.

Formidable. Stoic. Stern. Driven. All words that would traditionally apply in a character description of Albert Michelson. But also: tennis, billiards, emotional fragility, loyalty, impulsiveness also apply. Michelson made the most important measurement of “zero” in the history of physics and yet never quite believed his own result, thinking it a failure. . . one he kept repeating over and over. After all, he set out to measure properties of the ether and ended up, inadvertently, showing that it didn’t exist! Yet, “everyone” knew that it had to. His path to that “failure” led him to create the most precise optical instruments ever devised, as well as a basic tool still used today on laboratory benches in spectroscopy and across continents in measuring the wiggling of spacetime in black hole and neutron star collisions. The first American to win the Nobel Prize, but not for his “zero,” but rather for his instruments.

1.16 The King of Electromagnetics and the Father of Electrons – Hendrik Antoon Lorentz

Primary profiles of: Hendrik Antoon Lorentz

Secondary profiles of: Pieter Zeeman, George FitzGerald

The Science: Electromagnetic forces, atoms, speed of light, Lorentz Contraction, and Lorentz Transformations.

The hardest courses that a physics graduate student will take are those in classical electromagnetism. (Among the hardest courses that a physics professor might be prevailed-upon to teach are those graduate courses in electromagnetism!) Hendrik Antoon Lorentz was the king of electromagnetism in the latter third of the 19th century as he mastered the mathematics and applied it to a new subject: the presumption of the existence of atomic particles of electricity rather than the traditional macroscopic-sized chunks of electrified or magnetized matter. He also took Michelson’s disappointing “zero” seriously and both figured out a solution (which was wrong) and worked out how to modify Maxwell’s interpretation to demonstrate a different solution (which was almost right). Grandfatherly in many ways, he was revered throughout physics for his kind nature and his formidable skills—he basically presided over theoretical physics as the guy everyone wanted to please.

1.17 Person of the Century – Albert Einstein

Primary profiles of: Albert Einstein, Meliva Einstein **Secondary profiles of:** Max Planck, Marcel Grossmann, Hermann Minkowski, Henri Poincaré

The Science: Simultaneity, motion in relatively moving frames of reference, the modern nature of mass and energy.

How in the world to write something original about Albert Einstein? We're going to see how a rebellious young man turned all of science, and a whole century to follow, on its ears. Over and over we see him ask simple questions that turn out to have complex and intricate answers. The Special Theory of Relativity figures into everything that followed him: remaking our understanding of space, time, the cosmos, and even quantum mechanics at a deep and mysterious level. It's not mathematically challenging, but for the first time, it's so counter to common sense that it's intellectually and logically challenging. Buckle in. Read closely, and prepare to be surprised, over and over.