SAMPLE

Special Relativity

Einstein's 1905 Revolution

Aira Astralis

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This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

In 1905 a twenty-six-year-old patent clerk in Bern published a paper with an unassuming title, On the Electrodynamics of Moving Bodies, and the physics of space and time ended. The young man was Albert Einstein, already three papers deep into the most productive year any physicist has ever had, and the paper's argument, compressed to a sentence, was that two facts everyone believed could not both be true, and one of them had to go: the Earth's measured motion through space, taken for granted for two centuries, was abolished in favor of something far stranger, the absolute constancy of the speed of light. What fell with the ether was the commonsense picture of time itself. In the theory the paper founded, special relativity, time does not run at one rate for everyone; clocks moving past one other tick differently, lengths depend on the watcher, simultaneity is a matter of opinion, and mass is a form of energy with an exchange rate the theory fixes exactly.

The strangeness of these claims is not in dispute; the point of this book is that every one of them has been tested, and every test has agreed. Time dilation is measured in the upper atmosphere by the muons that would not otherwise reach the ground, in particle accelerators by beams of particles that live a thousand times their proper lifetimes, in commercial aircraft by atomic clocks flown around the world, and continuously, in every phone that consults the satellites of the global positioning system, whose clocks must be corrected for their motion or the positions drift by kilometers a day. Special relativity is the most thoroughly confirmed piece of physics that was ever controversial, and its story, from the failed experiments of the 1880s to the relativity tests of the twenty-first century, is one of the great stories in the history of science.

The chapters follow the story in its natural order: the crisis the theory resolved, the two postulates that resolved it, and the consequences each in turn, from the relativity of simultaneity through time dilation, length contraction, the spacetime of Minkowski, the famous mass-energy equivalence, and the twin paradox with its careful, satisfying answer. Then the theory at work: the experiments that checked it, the technologies that now depend on it, the electromagnetism it unified, and the questions, from faster-than-light fiction to the searches for its violations, that it still frames. The book closes with Einstein himself, the patent office, the Nobel Prize that was not for relativity, and the stone-simple idea at the center of the century's most beautiful theory.

One note on the mathematics, promised at the start and kept here: this book uses none. The theory's working symbol is a single relation between two speeds, the relative speed and the universal speed, and every effect in the chapters is that one relation speaking in different directions; the trade's

expositions write the relation as a factor, and the reader who wants it will find it in any textbook, where it is the first line. What the book keeps instead is the logic, which is the theory's actual content and which no textbook conveys better than the original thought experiments: a postulate is worth a thousand derivations, and the chapters that follow are the postulates' consequences, in the order the century learned them.

Chapter 1: The Discovery of Special Relativity

The discovery of special relativity is the story of a problem that had been visible for half a century and a solution that arrived from an unexpected quarter, and the reader should begin with the problem. Light, by the middle of the nineteenth century, was known to be a wave, and waves, by everything experience taught, travel in something: sound in air, ripples in water. The something light traveled in was named the luminiferous ether, an invisible, all-pervading medium, and the physics of the day assigned it a paradoxical job description: rigid enough to carry the fastest waves known, at hundreds of millions of times the speed of sound, and insubstantial enough to let the planets pass through without the slightest resistance.

The ether was the reference frame of the universe, the backdrop against which light's speed was set, and the Earth, orbiting through it at a measurable clip, should therefore see light's speed vary with direction: faster downwind, slower upwind, exactly as a swimmer's progress varies with the current.

The experiment that tested this is among the most famous ever performed. In 1887, in the basement of a college in Cleveland, Albert Michelson and Edward Morley built an interferometer, an instrument that splits light along two perpendicular paths, recombines the beams, and reads their interference: any difference in the speed of light along the two directions, set by the Earth's motion through the ether, would appear as a shift in the pattern as the whole apparatus rotated through the directions of travel. The result was null, and the nullity was not for want of sensitivity: the instrument could have seen a fraction of the expected effect, and it saw nothing, no direction to light's speed at all.

The physics of the day spent nearly two decades failing to fix this: the most successful rescue, by Hendrik Lorentz, proposed that bodies moving through the ether contract along their direction of motion by exactly the amount needed to hide the effect, and the contraction, applied with mathematical completeness, produced a set of transformation equations, the Lorentz transformations, under which the ether became, in principle, undetectable.

The mathematics was finished before anyone knew what it meant, and two names deserve their share of the credit the story usually gives to one alone. Henri Poincaré, the greatest mathematical physicist of the generation, understood the transformations' group structure, saw that they made the ether inaccessible, and stated the principle of relativity in print before 1905: no experiment can detect uniform motion through the ether. What Poincaré and Lorentz never did was take the final step, the one that required no

mathematics at all: to declare the ether simply did not exist, that the constancy of light's speed was not a conspiracy of contractions but a fact about the world, and that time itself, in moving frames, was different.

That step was Einstein's, and it is the reason his name is on the theory: the patent clerk, working alone in Bern with no laboratory and no academic position, saw that the difficulty was not in the equations but in the concepts, and redefined the concepts, and the equations then fell out almost as afterthoughts.

The apparatus of the null experiment deserves its own description, because its principle is the century's most borrowed. Michelson's interferometer split light with a half-silvered mirror, sent the two halves along perpendicular arms, and recombined them at the eye: light being a wave, the recombined halves interfere, bright or dark according to whether their two paths' round trips differ by a whole number of waves, and the pattern's fringes are a ruler for differences of a fraction of a wavelength, distances smaller than any mechanical gauge could touch. Rotate the instrument and any direction-dependence of light's speed would swing the arms' roles, shifting the fringes by a computable amount; the 1887 run, the most sensitive measurement of its kind yet attempted, watched for the swing through the Earth's rotation and found a fraction of the expected shift, indistinguishable from nothing.

The instrument's descendants are the modern gravitational-wave detectors, the same split-and-recombine principle scaled to kilometer arms, and the reader may note the lineage: the experiment that failed to find the ether became the machine that hears black holes.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.