SAMPLE

Quantum Tunneling

How Particles Pass Through Impossible Barriers

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

Introduction

Throw a ball at a wall and the physics of the throw is settled before the ball lands: if the ball's energy is too little for the wall's height, the ball comes back, every time, and no number of attempts changes the verdict. Now shrink the ball to an electron and the wall to a barrier of electrical repulsion, and the verdict changes: the electron, arriving with too little energy to surmount, nonetheless appears on the far side sometimes, a small fraction of arrivals passing through a region it could not classically enter, the passage leaving the barrier intact and the electron whole.

This is quantum tunneling, the penetration of barriers by objects that lack the classically required energy, and it is among the most consequential of the quantum facts: the sun's fusion runs on it, radioactive decay is governed by it, the modern era's memory chips write with it, the sharpest microscope ever built sees with it, and the enzyme chemistry of life uses it, the universe having made the impossible merely improbable and then built stars, elements, and industries on the improbability.

The book tells the phenomenon's full story in the series' plain prose: the alpha-decay puzzle that forced the discovery and the young theorists who cracked it from the new wave mechanics; the classical wall's logic and the wave's answer, the evanescent tail that reaches through; the sun's own dependence on the tunneling arithmetic; the microscope that images atoms by tunneling's sensitivity; the diodes, memories, and superconducting junctions of the electronics age; the chemistry and biology of proton and electron tunneling, stated with its honest evidential standing; the tunneling-time puzzle, the trade's longest-running argument about how long the impossible takes; the folklore honestly corrected, including the energy-borrowing myth; the interpretations' readings; and the working world's ledger, every machine sorted by what the tunneling does. The settled physics, the standard readings, and the open questions are labeled throughout, as this series does, and the reader who finishes will hold the plainest of the quantum gifts: the wall is not a wall to a wave, and the world runs on the difference.

A note on the book's compass, because the subject's span is unusual even for a quantum topic. The chapters run from the nucleus to the sun, from the factory floor to the living cell, from the attosecond laboratory to the speculative cosmology, and the reader may wonder what holds the tour together; the answer is one arithmetic, the exponential tail, applied at different scales, and the book's method is to show the arithmetic working at each stop, with the dials, width, height, mass, set differently by each application, the sun's barrier being hot and wide, the memory's being

engineered thin, the enzyme's being shaped by protein, the unity being the equation's own. The reader who finishes a chapter and doubts the connection may check the dials' settings against the tail's steepness, and the tour will close itself, every stop being the same physics at a different compression, which is the series' standing test for a subject worth a whole book, and this one passes at every gate.

Chapter 1: The Discovery: The Decay That Would Not Behave

The discovery began with a scandal in the atomic nucleus, and the reader should know the scandal plainly. Alpha decay, the emission of helium nuclei from heavy elements, was measured with exquisite precision by the radiochemists, and the numbers were impossible: the emitted alphas had energies far too small to escape the nucleus by any classical account, the nuclear barrier being many times their height, yet the escapes happened, slowly, steadily, with clockwork half-lives; and worse, the half-lives varied over fantastic ranges, elements neighboring on the energy scale differing in decay rate by factors of billions of billions, the uranium alphas crawling out at energies the radium alphas exceeded, the whole business defying the mechanics that governed everything else. The classical picture was trapped: the alpha, inside the barrier, could not get out; outside, the observations said it did.

The resolution came from the brand-new wave mechanics, and it came fast, from two directions at once. George Gamow, the young Russian physicist working in Europe, and, independently, Ronald Gurney and Edward Condon in Britain, applied Schrödinger's 1926 equation to the nuclear barrier in 1928 and found the answer in the wave's own arithmetic: the alpha's wavefunction, meeting the barrier it could not classically cross, does not stop at the wall but decays through it, an exponential tail reaching the far side, and the tail's small amplitude there is a probability of emergence, tiny but real, the escape being neither a leap over nor a drill through but the wave's reach through the forbidden region.

The calculation's triumph deserves the reader's attention: the exponential's steepness, fixed by the barrier's height and the alpha's energy, reproduced the observed half-lives' fantastic spread, the billion-billion factors falling out of the arithmetic in the right order, the wave mechanics having passed its first great test on a problem classical physics could not even state correctly, and the trade's textbooks have opened the tunneling story with the alpha ever since.

The discovery chapter owes the reader the scene's human texture, because the 1928 resolution's players became the century's own. Gamow, the young emigre with the constitution of a bear and the trade's best party trick, carried the alpha-decay manuscript to the Solvay-era gatherings and found the senior physicists initially disbelieving, the nucleus's transparency being too strange, until the arithmetics were checked and the tables matched; Gurney and Condon, the quiet Cambridge-and-Princeton pair, found the same result

independently and published within weeks, the two papers' agreement being the new mechanics' own coming-of-age, the wave equation having been three years old and having cracked a twenty- year scandal.

The reader should hold the timing's meaning: the wave mechanics arrived in

1926, and by 1928 it had explained the decay the classical era could not state, the speed being the trade's own measure of a right theory, and the alpha's tail having been one of the new equation's first two or three triumphs, the discovery's arc being the quantum's own announcement that the forbidden was negotiable, the nucleus having opened its ledger before the decade closed.

The discovery chapter's second debt is the name's own history, because the vocabulary arrived with the physics and settled slowly. Gamow's own papers spoke of the transparency of the barrier, the nucleus being transparent to the alpha's wave, the word transparency being the trade's first honest label, the optical metaphor being apt and lasting; tunneling as the settled name arrived with the English-language pedagogy of the 1930s, the word capturing the passage's image at the cost of the passage's subtlety, the reader having now seen why the optical cousin of this book's earlier chapter, the evanescent leak, is the more exact picture, the transparency being the truth and the tunnel the metaphor.

The reader should hold the naming's lesson: the physics' best images are borrowed from the older waves, the light's glass having taught the matter's tail, and the trade's vocabulary preserving the kinship in its own etymology, the forbidden region being crossed by a transparency the classical world denied, the name being the subject's smallest monument, settled, like the half-lives, by usage's own arithmetic.

The discovery's third debt is the two-teams' parallel note, because the independent arrivals' coincidence deserves the honest telling and the trade's own handling of it. Gamow's manuscript, carried to the summer schools of 1928, having been shown around the European circuit; Gurney and Condon, at Princeton, having found the same barrier arithmetic in the same months, the two papers' near-simultaneity being the era's own signature, the new wave mechanics being in the air and the nuclear puzzle being the era's standing scandal, the same tool meeting the same scandal in two places at once, the trade having handled the coincidence generously, both papers standing in the citation lineage, the history's honest note being that the discovery's time was ripe rather than lucky.

The reader should hold the ripeness's meaning: the great resolutions often

arrive twice because the tools and the puzzles meet at their moment, the 1928 double arrival being the pattern's cleanest case in this subject's history, the tail having been found from two directions, in one year, by young men who had both learned the new equation and both read the old decay tables, which is the sciences' own quiet recipe, and the reader having now seen it work.

End of free sample. The full book is available at putrabooks.github.io

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.