Quantum Theory as a Mechanical Modeling Problem

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Abstract: What happens to physics theories when adding dimensionality is reinterpreted not as free but as something costly to avoid until absolutely necessary? An answer to this question already exists: You get a mechanical model that worked so well in electromagnetism that James Clerk Maxwell used it to prove that light is a form of electromagnetic radiation. This article briefly discusses two examples of mechanical models that necessarily require using low dimensionality: Maxwell's 1862 "molecular vortex" model that uncovered the nature of light, and Walker Lee Guthrie's 2012 fast-sinusoidal-transition model that may provide insights on quantum state transition dynamics.

The First Field Theory Was Mechanical

The concept of using mechanical models to capture and predict critical behaviors in complex physical systems goes scale beyond models. For example, did you know that James Clerk Maxwell first determined light to be electromagnetic [1] not by using differential equations — those came later — but by constructing an aether model in which he filled space with tiny twirling mechanical vortices (Fig. 1)?

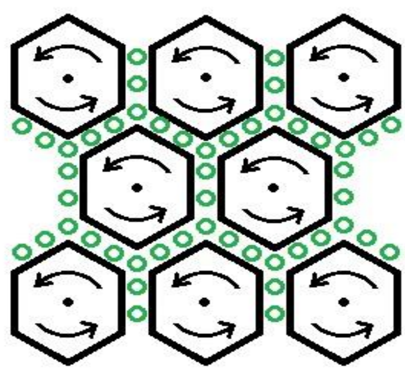

Figure 1. *A graphical representation of Maxwell's 1862 rotating vortex cells. He developed the model in stages, adding just enough complexity to capture all known rules of electromagnetism. He later converted the mechanical rules of these cells into quaternion differential equations, which Heaviside converted decades later into the four more compact vector-notation equations we now call Maxwell's Equations. The fact that Maxwell first captured the logic of his equations in mechanical form — and only later converted them into differential equations — remains one of the most unique derivations of a new physical theory. (Image: 老陳 CC BY 3.0)*

Due to that success, Maxwell's fully mechanical sea of tiny whirling gizmos, all fully contained within three dimensions of space and one of time, readily qualifies as the first and arguably one of the most successful field theories. In addition to providing the rigor needed to predict the speed of electromagnetic radiation traveling through his aether of spinning cells, his mechanical model contains subtle hints of the relativistic ([2]; see final quote from Chapter 12) and quantum revolutions that Maxwell, alas, never lived to see due to his untimely early death. His was the first theory that showed how to represent particles — photons — as excitations of an aether of oscillating mechanical devices. His pre-quantum version of photonic fields did not need the yet-to-be-discovered effect of quantization, yet even was as capable of supporting it as modern quantum field theories that, to this day, add quantization to their fields in an *ad hoc* fashion by simply making it an operator whose physical meaning remains mysterious.

Ironically, the same Maxwell who played a critical role in transforming physics into a discipline of differential equations began his journey with an adamant insistence on first creating *mechanical* models of his ideas [2]. The early philosophical stance of Maxwell was that if there was no mechanical equivalent to some dynamic behavior proposed to exist in electrodynamics, then that behavior likely did not exist or had been misunderstood. His approach stands in stark contrast to the modern descendants of Maxwell's first aether theory, such as superstrings, that keep the idea of a fixed sea of shifting vibrations but discard any need for comparisons to everyday classical physics with severely limited dimensionality. Yet Maxwell's mechanical aether strategy served him well by providing a sufficiently precise quantitative model to show that electromagnetic and light waves are one and the same thing.

The Curious Case of Low-Dimensional Field Theories

The trickier question about Maxwell's molecular vortex model is this: If physical reality is inherently hyper-dimensional — that is, if modeling reality *requires* high numbers of dimensions, as in quantum theory's extensive use of infinite-dimensional Hilbert spaces — how could Maxwell's model possibly have worked? Shouldn't any kind of mechanical model be incapable of the complexity needed?

For example, the perceived need for additional dimensions to model experimental physics is why "super" string theories never use less than ten dimensions. (The best designation is "super" strings because the original data-driven string 1960s string theory turned out to be an incomplete theory of quark orbitals. Quark orbitals are much "stringier" than electron orbitals.) Superstring theories assume astronomically dense packing of these into resonators to form the aethers we perceive as Lorentz-invariant vacuums.

Incidentally, that kind of extreme packing of complicated resonators is the deeper source of the vacuum density problem: predictions of infinitely massive vacuums. If Maxwell had proposed that his molecular vortices were actual mechanical devices of tiny size, he, too, would have encountered the same infinite-vacuum density problem as modern quantum field theories. The two issues are closely correlated. Maxwell handled his vacuum density problem by recognizing that despite their representational abilities, his vortices could not be real machines. Modern quantum field theories cannot eliminate the problem that simply since we now know that vibration energy has gravitational mass independent of the resonators.

Maxwell appears to have intuited, rather than specifically worked out, that even ordinary three-dimensional space plus time has immense representational capabilities. His intuitions were correct, but, as anyone familiar with various symmetries of modern field theories, Maxwell had the good fortune to deal *only* with the electromagnetic force, which has a straightforward relationship to *xyz* plus *t* space. Even for this case, however, Maxwell (based on Faraday's work) still had the curious issue of defining how a "flux" of electric "something" could flow continually out of one static charge to another charge — which is the reason why, to this day, we talk about positive (outflowing) and negative (inflowing) charge types. Even for electromagnetism, some of the geometries suggested something more complicated was going on beneath the hood.

Maxwell's remarkable success in using a 3D mechanical field theory to determine the more profound nature of light brings up the issue that 3D observers, like fish in the ocean, may not fully perceive the complexity of their environments: 3D space and time are *already* immensely complex. The best proof of this is the complexity required to model space and time, even incompletely, on a computer.

Thus, the subtler question of Maxwell's mechanical successes is this: Was Maxwell's initial intuition of the power of lower-dimensional field theories abandoned *too* quickly in favor of the powerful symmetries and capabilities available in higher dimensional models? Is it possible the constraints of 3D space are not so much limits as they are reflections of deeper physics, thus allowing them to model more complex physics behaviors?

A Simple Mechanical Model of Quantum Energy Transitions

In 2012, engineer Walker Lee Guthrie devised a straightforward way to model electron energy transitions using nothing more than a stiff spring to represent the wave function and pressure to transition the function to higher energies [3][4]. Fig. 2 provides a slightly stylized portrayal of the video of his model covering two energy transitions.

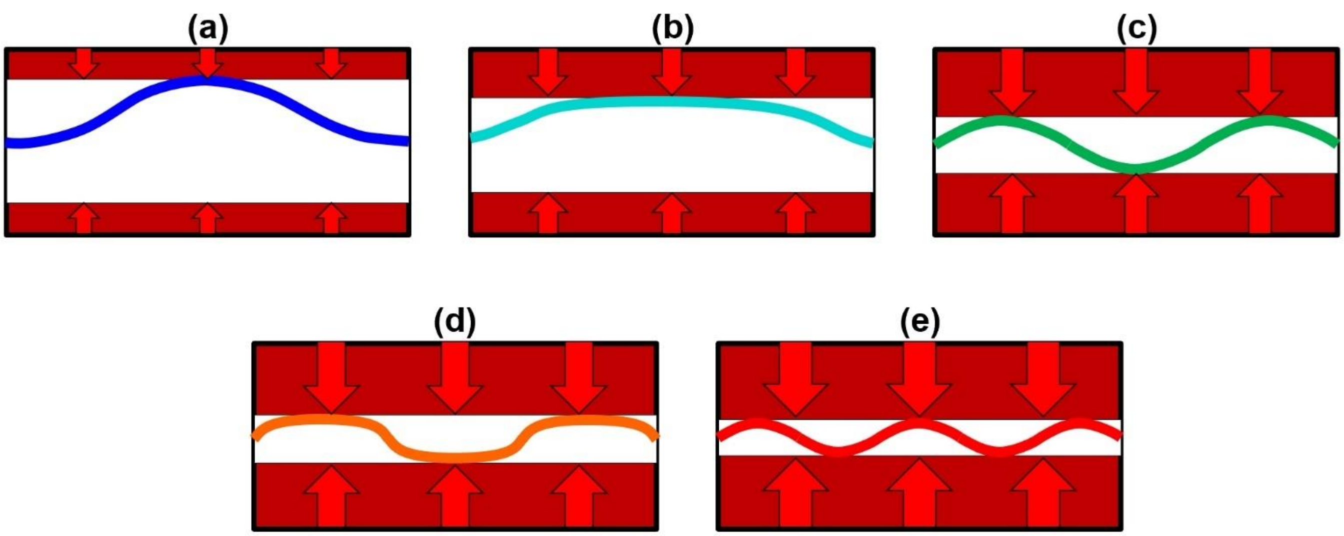

Figure 2. *Idealized images of Guthrie mechanical quantum transition model, closely based on images from compression experiments. Blue indicates the lowest-energy (base) state, while red indicates the highest energy state. Note the how the peaks flatten and sides steepen immediately before each extremely rapid transition, implying that the simple harmonics of the stable states convert into complex superpositions of higher harmonic states immediately before restabilizing.*

What is particularly notable in the video [4] of the Guthrie quantum wave transitions is the speed of the energy state transformations after the initial distortions of the simple sinusoidal wave corresponding to standing waves. An emulator of this simple form strips out most of the complexity of the wave function yet keeps the most critical part: How does the addition of energy enable a quantized transition? This simple example suggests that even today, there is potential in Maxwell's mechanical approach for quantum insights.

(Special thanks to Lowell Rosen of MITRE for first alerting me to Maxwell's vortex work.)

References

[1] J. C. Maxwell, *III. On Physical Lines of Force: Part III. - The Theory of Molecular Vortices Applied to Statical Electricity.*, The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science **23**, 12 (1862). https://www.tandfonline.com/doi/pdf/10.1080/14786446208643207.

p. 12: "… magnetic induction may be accounted for on the hypothesis of the magnetic field being occupied with innumerable vortices of revolving matter, their axes coinciding with the direction of the magnetic force at every point of the field. The centrifugal force of these vortices produces pressures distributed in such a way that the final effect is a force identical in direction and magnitude with that which we observe."

p. 22: "… 193,088 miles per second [is] The velocity of transverse undulations in our hypothetical medium … we can scarcely avoid the inference that *light consists in the transverse undulations of the same medium which is the cause of electric and magnetic phenomena*."

[2] B. Mahon, *The Man Who Changed Everything: The Life of James Clerk Maxwell* (Wiley, 2003). https://www.google.com/books/edition/The_Man_Who_Changed_Everything/6xKMT61cTcAC.

Chapter 7, *Spinning Cells*. "[Maxwell] chose … to go beyond [Faraday's] geometrical analogy and make an imaginary mechanical model of the combined electromagnetic field — a mechanism that would behave like the real field. If he could devise a suitable model, the equations governing its operation would also apply to the real field."

Chapter 12, *Maxwell's Legacy*, Note 1: "Astonishingly, these modifications to space and time seemed to be intrinsic to Maxwell's equations of the electromagnetic field: they worked perfectly under Lorentz's transformation."

[3] W. L. Guthrie and R. R. Davis, *Quantum Spring Invention: Engineering Analysis and Test Evaluation*, Convergence Engineering Corp. (2012). https://www.linkedin.com/in/walker-lee-guthrie-8b510028/overlay/1635537820016/single-media-viewer

[4] W. L. Guthrie, *Modeling the Schrödinger Probability Wave Equation [Video]*, Sampling the Multiverse (YouTube) (2012). https://youtu.be/wrBsqiE0vG4