## Connections: Physics, Math, \& the Human Brain

## James L. Hoover

Introduction: Building the Essence of the Physical World.
By most measures, the connection between physics and mathematics is not tricky, helps to reveal sometimes shocking truths, and aids the unraveling of deep mysteries. Like poetry, it can inform with stunning brevity the secrets and the beauty of physical life as we know it and at the same time as we might dream of it.

There is often a certain sterility to definitions of anything, definitions which fail to enliven or substantively inform. Mathematics, according to Merriam-Webster, is "the science of numbers and their operations, interrelations, combinations, generalizations, and abstractions and of space configurations and their structure, measurement, transformations, and generalizations." Physics is "a science that deals with matter and energy and their interactions."

The first definition bleaches out the vital dynamics of mathematics when it interacts, especially with a physical world - both quantum and macro. The second is like a stalled singularity, which omits a vital constituent, like antimatter in the definition. Quantitatively, we've measure it, with the same mass as matter. Experiments show an opposite charge. Building a knowledge base, we've documented it as short-lived and volatile, though a linchpin for steering us to the future, like matter's potential energy that Einstein's simple, but profound $E=m c^{2}$ revealed.

With the Santilli telescope, the first detection of anti-matter galaxies ${ }^{i}$ occurred, utilizing a new isodual mathematics. Here on Earth it's harnessed for medical brain scans. But basically, matter's definition tells a flat, vague and indefinite story with no qualities of ghostly dark matter and dark energy, neither directly seen but constituting $24 \%$ and $71.4 \%$ of the composition of the universe, respectively.

Separate, math and physics seem static, and incomplete. Together they are vibrant, dynamic and vital. Married, the union offers more substance. Together, they supply proofs, furnish structure, provide order, clarify and vivify quests. Math enables computerized modeling, a sound hypothetical footing, more logical reasoning and quickened quantitative calculations, which can process mountains of data and is capable of dispelling one hypothetical solution after another in rapid succession.

Math is considered the underlying language of science and physics, a way to express concepts, visualize images, depict differences, and model variables. To this end, areas of study have their mathematical tools. For example, classical mechanics has calculus; electromagnetism, vector calculus; General Relativity, differential geometry. There is Quantum Field Theory, matrices and group theory, superstring theory, and knot theory. Each new development often requires a new
branch of math, like Albert Einstein, for example, needing clarity for his theory of general relativity, thus utilizing new ventures into Riemannian geometry.

It's easy to expound on litanies of math tools used in various physics realms, but experience does demonstrate math's poetic ability to draw together disparate ideas and images with a single identity.

Euler's Identity: "a wormhole between separate branches of math," Lee Simmons."
Perhaps one equation best represents it metaphorically, if not in principle. Being an equation that combines popular real, imaginary, transcendental, and complex numbers that beg application and is combined into a single equation, Euler's identity is perhaps a perfect example, with e , the exponent at 2.1718..., i , an imaginary number, pi at 3.14159..., and constants, 1 and $0: \mathrm{e}^{\mathrm{i} \mathrm{\pi}}+\mathbf{1}=\mathbf{0}$.

It has three basic arithmetic operations: addition, multiplication, and exponentiation, and links five fundamental math constants. You have the continuous growth of exponents, real and imaginary, the real pulling forward and the imaginary coursing toward 90 degrees and rotating. With this identity and its projected functions, you can depict helixes, waves, and circles on a Cartesian coordinate and imagine a helix over time. The formula equates disruptive, exponential change (the realm of e) and infinite repetition $(\pi)$, but magically gives engineers, for example, easy authority to convert trig problems (sines, secants, etc.) into more manageable algebra.

All this is not to say that one equation is the ultimate elixir of understanding, but it does lend consideration to multifaceted concepts in the combined realm of math and science.


Euler's formula does 2-dimensions in a circle and a Cartesian coordinate system. Add time or direction for another dimension (z) of a continuous coil. Move to the side \& the coil or helix becomes a sine wave. ${ }^{\text {iii }}$

Brain's Digital Brother: "Brains are analogue; computers are digital," Chris Chatham. ${ }^{\text {iv }}$
Early civilizations sought deductive arguments using mathematics structures when found to be good models of real phenomena. Practical math as rigorous arguments first appeared in Greek math around 300 BCA in Euclid's Elements. Axiomatic systems came late in the $19^{\text {th }}$ century, establishing dependable truths, saving thinkers and experimenters the time and energy of rediscovering these truths. General purpose computers began performing digital mathematical functions in the middle of the $20^{\text {th }}$ century, a great aid to the study of physics.

Fundamentally, physics depends on the human brain and accompanying senses to investigate the physical world around us. Both have consistency failings in studying the physical world, which the mathematics-based computer and all digital-based human-produced software do not ${ }^{v}$. "The human brain is analogue; computers are digital."vi Unlike the human mind, computers are binary-based (1's or 0's), that is until quantum computers are perfected. When this happens, math, in computer form, will imitate quantum physics rather than its more common function of representing the physical world.

Dependence on the computer aptly represents the vital role of mathematics in physics and physical studies. Mere mortals have tried to fashion a math that mimics mental functions associated with the human brain. Euler's identity incorporates most. To wit, in simple terms, the right-brain performs the imaginative functions, the poetic, the transcendental, those permitting speculative thought. It excels in music and art. The Euler identity, the metaphor and the poem of math without the fancy of the brain, represents imaginary numbers for "out-ofbox" calculations, transcendent numbers, the concept of 0 -- or nothing, even the sonification of the physical world. ${ }^{\text {vii }}$ But overall the equation's math accommodates the left-brained rational and explanatory processing.

In our connections realm, $G_{t}=(P+M+B)_{o}(1+r)^{t}$ might be our equation, considering the energy the combining of Physics, Math, and the Human Brain brings to discovery, development and Growth, at a certain rate over time. You might say that the growth of the elements on the right side of the equation is rendered exponential by an interconnected dynamic. Any differential growth or feedback function for each element could be developed and added. The equation is much like $E=\mathrm{mc}^{2}$, in the near light-speed physical mass being brought to us in waves from the early universe to contribute to the rising energy of our discoveries, its resolution and effectiveness depending on $\mathrm{P}, \mathrm{M}$ and B . It also reminds us of the elements and symbols of Euler's identity.

We are saying that physics needs both the analogue brain and the digital computer. Repeatable truths and consistent evaluations cannot unequivocally be furnished by the human brain but can by the computer. Accurate models of the brain have to consider some " 225 million billion
interactions between cell types, neurotransmitters, neuromodulators, axonal branches and dendritic spines,","viii for example. This isn't even a total inventory of influences. Accordingly, replete with these interactions, the brain is subject to moods, emotions, injury, bias, and rationality lapses not found with the computer and math.

Now of course, all the guidance comes from human interactions (vetted by other scientists like BICEP2) with the computer and its programming, including equations, algorithms, models, and such. Just as our understanding of the whole universe is built on the study of its selected parts, we can show how some of the greatest strides in physics, from the Large Hadron Collider (LHC), to DNA mapping and to studies of the unseen quantum world, resulted from a teaming of the human brain, computers, and math.

Math's Applications: "Mathematics is the door and the key to the sciences" Roger Bacon. ${ }^{\text {ix }}$
Everyday applications from driverless cars negotiating streets and highways, to satellites in close orbits of the Earth require sensors that provide constant positioning with millisecond reaction times, such as software algorithms used to avoid satellite collisions, for example, the U.S. Iridium 33 collision with the Russian Cosmos 2251 in 2009. ${ }^{\text { }}$

In science, there have been many false starts, repeated mistakes, and many trial-and-error exercises, but no LHC could ever materialize without the consortium of the human mind, math and computers. Consider LHC's four million lines of computer code (LOC), its output of five gigabytes of data every five seconds of operation, hundreds of snapshots of particle collisions per second, the over 7000 scientists grappling with the unfolding mysteries the LHC is expected to bring.

Then there is the gathering of scientific knowledge in the massive database containing all elements and concepts of the Standard Model, including its math which predicted most basic particles of the last 40 years. There are all interactions of colliding particles from previous colliders - all essential knowledge required for millions of algorithms to look for the Higgs boson, dark energy, dark matter, supersymmetry, the secrets of anti-matter, and involved physicists wanting to get their arms around the mysteries of physics -- one of the biggest, the Higgs particle. The most basic guides would be equations that model high-energy particle collisions which create short-lived high temperature plasma of quarks and gluons.

Out of hundreds of millions of protons circling LHC's 17-mile-long circle near the speed of light, magnets cooled to near absolute zero (remember the 0 in Euler's identity) to keep the protons on track, and two detectors, Atlas and CMS, checking for anticipated particles and a certain upsurge in energy that Higgs particles would produce. Algorithms narrowed down the range of

GeV to look for. In fact, the energy surges came and Higgs was announced at a mass of 125.3 GeV . This particle addition to the Standard Model could never have happened without computers and math. Essentially, modeling the Big Bang is leading to questions and answers about life itself.

The mysteries of life and its evolution have been hidden from our view since the dawn of humankind. Wrapped in two molecules of helix shapes is the secret of each unique existence, begging questions of space, time and human destiny. It's a universal shape represented by pi, shaped by the force of gravity in space, made contiguous in ubiquitous strands in each cell of our body. Computers and math supported its discovery and mapping.

More advanced sequencing of the full genome of DNA occurred by 2005. The venture, given that DNA is composed of 23 pairs of chromosomes and that the DNA of humans consists of approximately 3 billion nucleotides (base pairs), was quite formidable. The Human Genome Project (HGP) started in 1990, aimed to map all of them, but was a prodigiously expensive project.

At this date, eight percent, some being heterochromatin areas, ranging from regulating genes to protecting the integrity of chromosomes, have not been mapped. Mindful of the cost and the overwhelming importance of its science, much was devoted to developing new and better computational tools to make gene hunts faster, cheaper and practical for almost any scientist to accomplish.

Computers and mathematics were vital in informing the highly complex DNA physics study. Now the physics of DNA is informing the computational business of cell study and perhaps even quantum biology. Tiny DNAbased computers are under development for implantation in human cells, analyzing chemicals or proteins in a cell, for one to conduct tests to diagnose malaria.


Math's Quantum Modeling: "I have an old belief that a good observer really means a good theorist," Charles Darwin ${ }^{\text {xii }}$

Mathematical formalisms of physical systems have three basic ingredients: states, observables, and their dynamics, operating over time. Classical descriptions are given in a direct manner by a phase space model of mechanics. Its mathematical forms involve the observable macro world of existence subject to forces known to the senses or by recognized physical laws. A quantum description sees physical values of a sub-atomic particle as spectral values of linear operators in Hilbert space.

Quantum states of particles act differently. They have a wave-particle duality. Highly perturbed, a hydrogen nucleus can tunnel through energy barriers in the Sun's core, for example. And there is quantum superposition of particles until measured - namely, a sub-atomic particle can occupy all of its possible quantum states until measurement separates and reconstitutes a different quantum state, one which Heisenberg concluded reveals only one measurement.

Fifty years ago, based upon his mathematical equations, the Irish physicist John Stewart Bell, posited in an article, quirky by most physicists' standards - even by Albert Einstein - that twin particles, such as electrons, could be entangled, meaning that even if galaxies apart, both in a state of superposition, one could be measured and instantaneously affect the behavior of the far-off twin particle faster than the speed of light. Under scrutiny, this theory has held up.

Now the math of a Type 0 civilization like ours, one that doesn't fully utilize the energy of our own star, does not include the possibility of superluminal speed in its theorems. However, quantum mechanics seems to leave the window open slightly with quantum entanglement, perhaps a world beyond a type 0 civilization. Could this be an example of Goedel's incompleteness theorem?

As our study of the world of quantum physics seeks to fill the voids of the Standard Model, there consistently unfolds great doubt about out-of-the-box findings. With the almost total mapping of the DNA genome, made possible by a better understanding of quantum mechanics, the emerging field of quantum biology introduces such findings that seem out-of-the-box as well.

While the world of quantum mechanics is a random, perhaps stochastic world, macro-world objects it constitutes are not. Atomic orbital mathematical functions feed into molecular orbital functions, represented as a linear combination of atomic orbitals, xiii usually constructed from a superposition of atomic orbitals belonging to the atoms in the molecule.

Such modeling and a global computer network have helped to better understand the interrelationships of the macro and the quantum worlds. Seemingly functioning like separated entangled particles, a theoretical physicist and a molecular genetics professor combine DNA knowledge we have accumulated with quantum mechanics, making strides in understanding the human body and creatures with which we share our planet, for one, the European robin.

Startling studies make this quantum-classical tie. They include the plant world where photosynthesis achieves a whopping 95 percent energy transfer efficiency rate of solar energy, attributed to quantum entanglement and superposition by a Berkeley scientist, and the navigation of the European robin loosely traced to the same state of quantum entanglement. ${ }^{\text {xiv }}$ The latter study combines cryptochrome, a receptor for the avian chemical compass, with a protein capable of generating entangled electrons, supposedly in the robin's brain. These mechanisms help the bird's North-South guidance, interacting with a weak magnetic field of the Earth. The "spooky" world of quantum mechanics is enjoining biology with a quantum flavor.

Conclusion: "Pure mathematics is, in its way, the poetry of logical ideas."Albert Einstein. ${ }^{x v}$
It is clear that math is not only a means to represent physical reality as we know it and as we might theorize it, for all its tools have been fashioned to represent rigorous and innovative thinking through centuries of inquiry by curious minds. But our physical discoveries have likewise created and enhanced existing models and tools. Like the exponential function represented in Euler's identity, our growth of knowledge and of mathematical tools has been exponential, forming an ever larger circle of knowledge and tools, like the universe, the fabric of knowledge-space grows. The imaginary number "i" (when squared, -1 ) is necessary for solving many problems in algebra and participates in applications for understanding electricity, light waves, and quantum mechanics. Instead of exponential growth that drives us forward, it rotates us into a circle of sustained existence. In physics, many things in the quantum world we can only imagine. The imaginary number represents that.

The Euler identity generalizes the math function, perhaps even more so for physics. The "unreal" must be theorized, for example, regarding the quantum world's connection with the classical world. In the LHC computer network, models incorporated results of past colliders, and algorithms controlled the near-light-speed circuit of protons. They provided guidance to detectors and identified plasma debris. A network of scientists, math and machines helped to identify and add the Higgs particle to the Standard Model database. Thus this assemblage of math, machines, physics and brain power, in mimicking the conditions of the theorized Big Bang, augmented a knowledge base, accruing growth to all network components.

Other quantum studies looked at the spooky world mentioned by Albert Einstein, where atomic orbital models joined molecular orbital models, looking at atoms as constituents of molecules. All quantum-world models speculate, utilizing some 100 years of research and observations, not being able to actually see the quantum world. Advances in DNA, understanding double helixes, a form aptly shown in projected functions of the Euler identity, clarified the road to uniqueness among humankind. We are slowly raising the curtain on the role and functions of quantum in the world of living creatures, guidance for understanding navigation of birds and
photosynthesis of plants, for example. We are beginning to understand how quantum features contribute to mysteries of the classical world we've modeled for centuries.

Without math and computers to furnish an easily accessible store of knowledge, models readily updated with new discoveries, without the precision algorithms offer, without speculative model runs, we would not be in space, looking to distant stars and galaxies; we would not be on the cusp of more $21^{\text {st }}$ century discoveries. Math and its digital connection, computers, coupled with the analogue minds of countless scientists, furnish discoveries which serve as exponents of one another.

We must conclude that we could never have built such an understanding of the physical world we live in, enlarging a perspective that spans proposed universes, perspectives built on Physics, Math, and the human Brain, some we can touch and others imagined with a measured certainty.

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