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WINNING THE WAGER: WHAT FAUST COULD HAVE LEARNED FROM PHYSICS

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NCIS is honored to publish this thoughtful piece by the late Dr Fannie Peczenik, which was presented to TIS by Dr Peczenik's husband, physicist Dr Donald H. McNeill, also a member of the Princeton Research Forum.

Fannie Peczenik (1947-2018) graduated in 1967 from Brooklyn College with a major in foreign languages. Her Ph.D. thesis at the City University of New York (1981, English literature) was entitled "Adam's Other Self: A Reading of Milton's Eve." She joined the Princeton Research Forum when it was founded while she was working on her dissertation. Her writing and studies encompassed the following: literary criticism, from Milton to Mailer, etc.; animals and plants; travel and memoirs; short stories and a novel; translations (Italian, Yiddish, Spanish); editing (technical, language, for friends).

Preface

"Winning the Wager: What Faust could have learned from physics" is a personal reflection on a physics course for non-physics students given at the University of Pittsburgh at about the time of the centenary of Max Planck's proposal of the quantum hypothesis in December 1900. Planck was attempting to explain the (black body) spectrum of light from heated objects, a long-standing puzzle of nineteenth-century physical experiment and theory on which he had worked for many years.

So, what does Faust have to do with Planck? Planck was one of the most serious and disciplined men of science. Within 30 years his idea led to the revolution in physics known as quantum mechanics with the contributions of: Einstein, photoelectric effect; Bohr, atomic theory; DeBroglie, wave nature of electrons; Schroedinger, quantum theory; Heisenberg, quantum theory; etc. Faust's efforts to understand the world are of a pattern from his pre-scientific era and, guided by notions of predictability not followed in nature, he fails at his original purpose. Maybe, like so much of physics in 1900, he needed a quantum hypothesis. The irony of this misunderstanding of nature is central to many differences of method in the sciences over the centuries, from Faust, to Goethe, to Planck, to our times. Its significance is amplified further since in May of this year the basis of the international system of physical units for mass will be redefined in terms of a specified value of Planck's constant (essentially a fundamental constant, or conversion factor, available everywhere), rather than as a piece of platinum-iridium alloy of specified mass located in Paris (as it has been since the kilogram was defined about 200 years ago).

Fannie wrote and discussed her essay at length shortly before her death in mid-2018.

Dr Donald H. McNeill
Princeton Research Forum

> Our culture is foolish to keep science and poetry separated. They are two tools to open our eyes to the complexity and beauty of the world.
>
> Carlo Rovelli, *Reality Is Not What It Seems: The Journey to Quantum Gravity*

Some years ago, I took a brief course in quantum mechanics offered by a lifelong learning program. The instructor was highly regarded for his lucid undergraduate lectures, and to suit a class of older, recreational students, he boldly undertook to teach without recourse to mathematics, the normal tool of physics. Words had to carry the full weight of the discussion. The method worked surprisingly well to engage the class. In fact, for me, it opened a long-term entanglement (I use the term cautiously) with Planck's constant.

The universe we inhabit, the instructor explained, is possible only because of Planck's constant; without it, neither we nor our familiar environment could exist. Maybe it was the way he phrased the sentence -- I can't remember his exact words -- that brought a shock of recognition. Planck's constant was new to me, but I'd heard a description like that before. It echoed lines from Goethe's *Faust*.. "*Dass ich erkenne, was die Welt/ Im Innersten zusammenhält*" (translated literally: so that I'll see and know what holds/ the world at its innermost together).[1]

In Act I, we first see Faust at his desk in a dingy, Gothic room cluttered with books and papers. In a long monologue, he laments his intellectual failures and thwarted ambition. Ten years devoted to a thorough study of philosophy, law, medicine, and theology proved to be wasted labor. He learned nothing new, and certainly not what holds the innermost world together, by poring over dusty tomes. Frustrated and bitter, he has now turned to magic, hoping it will reveal the hidden workings of nature to him. With spells and symbols from a manuscript written by the hand of the Renaissance magus Nostradamus, Faust tries to invoke the aid of supernatural spirits. But sorcery fails him, too.

The way is then open for the devil Mephistopheles to arrive and offer Faust, if not the longed-for revelation of nature's secrets, at least the full sensuous human experience that his cloistered, scholarly life has denied him. Skeptical of the devil's promise, Faust wagers on disappointment and dissatisfaction. He makes a deal that if he ever finds a single moment so beautiful that he wishes to prolong it, he will gladly die and let Mephistopheles take his soul. With that wager, Faust's quest for knowledge becomes a quest for experience. It does not end well; the unhappy consequences of an aging professor trying to make up for lost time are inevitable.

Wasn't it interesting, I thought, that Faust's monumental craving for knowledge would, in real life, end in a mere number, a humble measurement? Conversely, my husband, who's a physicist, was amused that a couple of lines of hypnotically rhymed verse might be an apt footnote to Planck's constant, which he had never considered in need of embellishment. He teased me about writing an essay -- let it enter a time warp and break the boundaries of literary fictions-- on Planck and Goethe.[2] With the aid of several excellent popular books on quantum physics published in the last few years, I can now accept the challenge.[3]

When Faust opens the Nostradamus manuscript, he comes upon the sign of the Macrocosm and, contemplating it, imagines he feels its power coursing through his body. But he has deceived himself; the spirit of the Macrocosm eludes him. He then invokes the sign of a lower order, the Earth spirit, who scorns and rejects him. From the vantage point of later scientific developments, one wonders if at this point Faust shouldn't have abandoned the atavistic notion that worth is directly proportional to magnitude, and tried the least formidable sign--the sign of the Microcosm (Goethe does not say if such a sign is included in the manuscript but let's suppose it is).And of the Microcosm, he should choose the most minute, indivisible form of matter. It would

[1]Johann Wolfgang von Goethe, *Faust: Der Tragödie. Erster Teil*, in *Werke*, vol. 3 (Frankfurt am Main: Insel Verlag, 1966), p. 17.

[2]Unknown to us, the link between Goethe's *Faust* and quantum mechanics had already been explored decades before, but in a completely different vein. As Gino Segrè recounts in *Faust in Copenhagen: A Struggle for the Soul of Physics* (New York: Viking Penguin, 2007), in April, 1932 the annual physics conference in Copenhagen featured a humorous skit that adapted Goethe's play to the lives and discoveries of the physicists surrounding Neils Bohr. Planck's constant was not mentioned in the "Copenhagen *Faust*," rather, the skit focused on the neutrino, then the subject of much contention, which took the role of the seduced and abandoned Gretchen of the original.

[3]Both highly accessible to nonscientists and well-written are: Michael G. Raymer, *Quantum Physics: What Everyone Needs to Know* (New York: Oxford University Press, 2017); Carlo Rovelli, *Seven Brief Lessons on Physics*, trans. Simon Carnell and Erica Segrè (New York: Riverhead Books, 2016) and *Reality Is not What it Seems to Be,* trans. Simon Carnell and Erica Segrè (New York: Riverhead Books, 2017). Older but extremely valuable is Kenneth W. Ford, *The Quantum World: Quantum Physics for Everyone* (Cambridge, MA: Harvard University Press, 2004), as is Jim Baggott, *The Quantum Story: A History in 40 Moments* (Oxford: Oxford University Press, 2011).

ultimately lead him to a fact as extraordinary as anything conjured up by magic incantations or Mephistopheles -- that contrary to everyday experience, nature is neither orderly nor predictable. It is random and probabilistic, and at its core, at the subatomic level, swarm restless particles resistant to precise measurement, all governed by the ubiquitous Planck's constant.[4]

The first edition of Part I of *Faust* appeared in 1808. Some ninety-two years later, on Dec. 14, 1900, Max Planck, intent on solving the mysteries of black body radiation, presented his radiation law to the German Physical Society. He had spent weeks sequestered in his study (like Faust, except that Planck's study was most likely cleaner and airier) with data on radiated energy and frequency that had long confounded physicists. It was universally assumed that light was emitted continuously, but through insight or intuition Planck realized that the assumption was wrong: if light was emitted discontinuously(in "lumps," later called "quanta"), then the data suddenly made sense. Along with the discontinuity, it was necessary to have a constant -- he named it "*h*"-- that determined how much energy was contained in each of the "lumps."At that moment, quantum mechanics was born, although, of course, it would take many others to pioneer and develop the field.

Planck found he required the constant to explain the data. Yet that was only the first glimpse into its magnificent necessity. As the lecturer told my quantum mechanics class, we and the world around us depend on Planck's constant for our existence. It is the fundamental constant of nature; it is included in every quantum equation and determines the scale of the subatomic world. It is almost unimaginably small, a number that, in the quotidian reality we inhabit, we would tend to disregard -- less than one divided by a billion trillion trillion (in SI units).[5]The slightest change in the value of Planck's constant would spell doom for the universe as we know it. Make *h* smaller and the atoms will be smaller; make *h* larger and the atoms will be larger. Perhaps one could fashion a viable world with these atoms, but it wouldn't be a place we'd recognize. And if there were no Planck's constant, there would be no atoms: if *h* were equal to zero, electrons would be subject to the rules of classical physics and, spinning in their orbits, crash into the nucleus.[6]

Planck's constant is then the numerical nexus of the universe. Not only is it the scaling factor, it is also the great diversifier. All elementary particles of a given type are identical; when they interact, Planck's constant gives them separate identities.

"It's what makes all of these things that are the same different," as my husband said. [7] The Periodic Table of the Elements is the result. To me, that seems to clinch the argument. Not everyone is convinced. I tell a friend who's a particle physicist about my ideas. He disagrees.

"Gluons," he says, "they're what hold the world together."

Literally, he is right of course. Gluons are the "glue" of quarks -- the whimsical names of elementary particles are only one aspect of the strangeness of quantum mechanics to the uninitiated -- and are therefore the building blocks of protons and neutrons. This is indeed a strong argument in favor of gluons. But the spins of the gluons, like all subatomic particles, are measured by Planck's constant, aren't they? Then Planck's constant remains a singular requirement, while gluons, vital for building atoms, are one of many essential components of matter, along with electromagnetic fields, strong force fields, photons.

As though to underscore its primacy, Planck's constant will, in the near future, be used to define the standard kilogram.[8]At present, the kilogram is defined by an actual object, a cylinder made of iridium and platinum that is kept under three bell jars locked in a safe at the International Bureau of Weights and Measures on the outskirts of Paris. The cylinder must be polished with a chamois cloth every so often, which wears the metal down and causes change in its mass, as well as being, it seems to me, an undignified circumstance for a universal standard of weight. *h* will neither erode nor require housekeeping chores.

In one sense, it is satisfying to think of Faust's frustrated intellectual labors as looking toward Planck's constant. Goethe was a life-long amateur scientist and despite his Olympian standing among German writers, already

[4]Raymer, *Quantum Physics: What Everyone Needs to Know*, p. 129, notes that Heisenberg's well-known Uncertainty Principle -- that the position and momentum of a particle cannot be simultaneously measured with the same accuracy -- has been complicated by a misleading translation. The term Heisenberg used is "Ungenauigkeit," which simply means "imprecision" or "inexactness." The word "uncertainty" carries unwarranted psychological connotations.

[5]bid., p 100.

[6]Ford, *The Quantum World: Quantum Physics for Everyone*, p. 201.

[7]Dinner table conversation with Donald H. McNeill, Oct. 12, 2017.

[8]https://www.nist.gov/physical-measurement-laboratory/plancks-constant (accessed 2/11/2018).

established in his lifetime, fervently wanted his scientific work to be taken seriously.[9] He had particularly high hopes for his *Theory of Colour (Zur Farbenlehre)* in which he railed against Newton, his imagined opponent. But there was no real competition between Newton's physics and Goethe's speculations about the nature of color. The scientific community was not impressed; his work was ignored. And yet, wrong as he was about color, in his best known literary work, Goethe inadvertently provided an apt description of a discovery that led to a scientific revolution. That's a formidable accomplishment for two lines of verse.

It is not rare for poets to be interested in science. For a strong example, consider that in John Milton's *Paradise Lost*, an epic populated by characters drawn from biblical narratives and legends, there is only one contemporary figure -- Galileo. Milton left the question of a heliocentric or geocentric universe unresolved in the poem, but his admiration for Galileo, the "Tuscan artist," and his telescope, "optic glass," is undeniable. Nor was Goethe's rejection of Newtonian physics rare among writers and humanists of his time. They generally abhorred the deterministic, mechanical view of nature assumed by Newton and other early modern scientists such as Descartes.

Yet there is deep irony in an imagined conversation between Goethe and Planck via *Faust*. Goethe disapproved not only of Newton's world view but also of his methodology. Again, like many of his contemporaries, Goethe considered nature a living entity; he believed that applying mathematics to natural phenomena was a cruel constraint. He would have preferred that scientists concentrate solely on observations and limit their inquiries to what the human eye can see (effectively making scientific experimentation akin to painting and sketching; not surprisingly, his method worked better for botany and anatomy than for physics). So Goethe probably would not have been pleased to discover that what holds the innermost world together is expressed mathematically and not apprehended visually.

Nonetheless, Planck's constant might suit Faust's needs very well. Since he wagers on never finding satisfaction, even for a moment, then *h*, as the key to quantum mechanics, can help him win the wager with Mephistopheles. What is the likelihood that in the quantum world there is a moment, beautiful or otherwise, that can be caught and held for a while? None. Where precise measurement is impossible, where two identical experiments may yield two different results, where only probabilities can be calculated, where chance rules, there can be neither satisfaction nor dissatisfaction. Planck's constant reveals the deep truth of nature: to know what holds the world together is to know the limits of knowledge.

Faced with *Ungenauigkeit*, Faust would see that while his desire will never be fulfilled, nature is infinitely more interesting than he ever imagined. We can suppose that, wiser, he would not settle for pedestrian pleasures, as he does, at long last, in Part II, declaring he has found his beautiful moment in a disastrously bungled scheme for real estate development. And then he would not need the intervention of the Eternal Feminine and the eternally forgiving Gretchen to whisk him up to heaven. The study of physics, a subject notably absent from Faust's earlier curriculum, would suffice to win the wager with the devil.

Here I have, admittedly, given a fanciful alternative ending to *Faust*, but my experience points to the sober reality of the interplay between literature and science. I had come to an adult education class to hear about subatomic particles and found myself remembering lines from a play I'd first read in a college German class many decades before. Faust's uncompromising hunger for knowledge had thrilled my teenage mind. I didn't ask whether it was reasonable. Who wouldn't want to know what held the world together? But the undergraduate years are brief. Soon I had other interests; questions about what lies at nature's core were not among them. And suddenly, unsought, there it was -- *h,* the number that holds the innermost world together. If by then I had ceased to admire Promethean egotists like Faust, I was bemused to find, at long last, where his quest might end.

Quantum mechanics, even when taught by a gifted lecturer and modified to suit an audience with little or no scientific preparation, is difficult and demanding. Remembering how *Faust* had tantalized me made the labor easier, and later made me willing to grapple with popular quantum mechanics texts.

And in our tawdry political time, there is one thing more. It was bracing to enter the quantum world. I was frequently frustrated and befuddled, as though I had accidently crossed the border into a country with an exceptionally peculiar language and bizarre customs. But the exotic new world was also a haven, an escape from the pronouncements of cheap hucksters who dominate the headlines with their willed ignorance and disdain for thought and reason. To make the journey seemed imperative – and it was a pleasure.

[9]The subject of Goethe and science has been much studied. For a succinct summary of his views in the context of a biography, see Rüdiger Safranski, *Goethe: Life as a Work of Art* , trans. David Dallenmayer (New York: Norton, 2017), pp. 418-424.