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Abstract.

Three Steps Towards a Realistic Foundation of Quantum Mechanics.

1. The current quantummechanical theory, represented by Erwin Schrödinger's equation, presupposes the classical concept of energy, E = p²/2m. This concept is only a hypothesis. It emerges not from natural experience or experiment but from an idea: to calculate *in proportion to the distance covered*, that is, *as a „path integral"*, a moving system's theoretically conceived faculty called „work". But, since a path integral is not a time integral, this calculation does not consider the time of motion of the system. Ignoring this fact entails that when applying Schrödinger's formalism in some cases there results an apparent *timelessness of interactions* (instantaneous action at a distance, etc.).

2. The Heisenberg relations presented by Niels Bohr in his 1927 Como lecture show the four basic operators, ‚energy E', ‚momentum p', ‚time t', and ‚space s', forming an equation of products (ΔE x Δt = Δp x Δs = h). According to geometric proportion theory, Bohr's equation can be rearranged as to show a *quaternate proportion*: ΔE **:** Δp = Δs **:** Δt. The implicit proportionality factor here is not h but c (dimensions space over time, [L/T]). The resulting proportion between energy and momentum then is ΔE over Δp = c [L/T], or, more generally: E/p = c, or E = pc. It is a true equivalent to Planck's energy-frequency proportion, E/f = h = constant, but not to the classical E = p²/2m.

3. In theoretical quantum mechanics the energy concept E/f = h, or E/p = c so far is mostly related to photons. For material particles the concept E = p²/2m is used as an equivalent (photo effect, 1905). This concept, however, can be demonstrated to be incompatible with E/p = c. Now, since the Heisenberg relations can be shown to imply E/p = c *for photons and electrons as well*, the mistaken concept E = p²/2m can generally be replaced with E = pc. This step removes the disturbing mystical and weird implications of current quantum mechanics, even gives it back the status of a „theory of motion", which Schrödinger's equation based exclusively on E = p²/2m is not.

I

The current mathematical foundation of quantum mechanics is represented by the Schrödinger equation in the first place. Nevertheless I begin with Heisenberg's relations. These two relations are arranged around just four operators: ‚space', s, ‚time', t, ‚momentum', p, and ‚energy', E. All operators are symbolized by a „delta", Δ, as finite quantities. Heisenberg's theory deals with relations between these operators as they come to light in experiments. The meaning of the operators, space, Δs, time, Δt, and momentum, Δp, is well-known. But what about „energy"?

1. In the year 1925 Werner Heisenberg initiated the era of modern quantum mechanics. He found a matrix that led to the afterwards so-called Heisenberg indeterminacy relations:

$\Delta p \times \Delta s = h =$ constant. (1)

$\Delta E \times \Delta t = h =$ constant. (2)

The constant h is „Planck's constant" as known since the year 1900 when Max Planck had developed the basic formula that shows a proportionality between two variables: energy E and frequency f of radiation, that is, the quantization of energy E:

$E/f = h =$ constant. (3)

2. The Heisenberg relations (1) and (2): What do they tell us? They show an *inverse proportionality* between operators Δp and Δs, and also between operators ΔE and Δt. As is well-known, inverse proportionality means that, while one operator increases, the other one inevitably decreases, and inversely. Werner Heisenberg interpreted this fact as if it would demonstrate the impossibility of determining both inversely proportional operators at the same time, because (so he argued) the more precisely one of them would be determined the less precisely would the other quantity appear, so that it could not be measured exactly. Therefore the name „indeterminacy relations".

I doubt that Heisenberg's idea is valid. Imagine the product 2 x 4 = 8 as a model of inverse proportionality, the number 8 being the proportionality constant. Reduce the factor 2 to 0,2, then the inverse factor 4 will automatically increase to 40, so that 0,2 x 40 = 8 again, and so on. It is not a problem to measure both variables at the same time, to whatever small a quantity the first variable is reduced, so that the second one increases to whatever big a quantity. I dare say that Werner Heisenberg ignored the mathematical meaning of „inverse proportionality", and not only he. As a matter of fact, none of the early founders of quantum mechanics, and of their successors as well, ever used the terminology or the principles of proportion theory as a means to describe quantummechanical relations. Niels Bohr, instead, invented a new word, „complementarity", to describe a mathematical relation which Galileo, or Newton, for example, would have described as „proportionality" in terms of geometric proportion theory. This fact already proves that Niels Bohr and Werner Heisenberg were not aware that they were dealing with geometric proportions.

3. Bohr's ignorance of proportion theory culminated when he in the year 1927 held his famous „Como lecture". There he introduced to the public the Heisenberg relations according to

ΔE x Δt = Δp x Δs = h = constant [1]. (4)

But never he nor anyone else to this day realized the true content of this formula.

The formula is a so-called „equation of products": The product (ΔE x Δt) equals the product (Δp x Δs). The constant factor h which both equations result in, ΔE x Δt = h; Δp x Δs = h, must not be made explicit. It is given implicitly with the formula ΔE x Δt (= h) = Δp x Δs.

Now, whoever knows the principles of geometric proportion theory also knows that such an *equation of products* can be lawfully rearranged to show a *quaternary proportion,* according to the rule: „The quotient of the inner terms equals the quotient of the outside terms" [2]. By rearranging ΔE x Δt = Δp x Δs accordingly we get

ΔE **:** Δp = Δs **:** Δt (5)

The implicitly given constant of proportionality, however, evidently is no longer Planck's h. What constant governs this quaternary proportion (5)? Since both sides of eq. (5) must result in the same constant, we get

Δs **:** Δt = c = constant (6)

and

ΔE **:** Δp = c = constant (7)

In both cases, the „new" constant c revealed with eq. (6) has dimensions „space over time" [L/T]. It is therefore identical with the well-known c of modern physics, called „vacuum velocity of light". Planck's constant h has vanished.

The energy operator then is

ΔE = Δp x c = constant,

or more generally:

$E/p = c = constant.$ (8)

Since the constant c is a quotient of elements of space and elements of time, eq. (8) contains all four operators, energy, momentum, space, and time that form the basis of quantum mechanics according to Heisenberg's relations. But, as the operator ΔE is brought to light in eqs. (7, 8) being proportional to the operator Δp of momentum, this „energy" is evidently not an equivalent of the classical term „energy" (kinetic and potential). In other words: The classical kinetic energy formula $E = p^2/2m$ is not proportional to momentum, so it is not an equivalent of the quantummechanical energy, which is $E = p \times c$ according to the Heisenberg relations as demonstrated. Moreover note that classical kinetic energy $E = p^2/2m$ is a *scalar*, while the term $E = p \times c$ is a *vector* („Poynting vector"). Ignorance of this basic difference between incompatible energy terms was and is the reason for many errors. For details see my 1990 paper „Does Quantum Mechanics Imply the Concept of Impetus?" [3].

4. John Henry Poynting in 1884 was the first to derive the formula (8) from the Maxwell equations. $E/p = E/mv = c = constant$ appears again in 1905 with Albert Einstein's nonrelativistic proof of $E = mc^2$ [4]. In 1930 Werner Heisenberg presents $E/p = c$ in his book „Physikalische Prinzipien der Quantentheorie" under the headline „Partikelbild der Strahlung" [5]. So this formula $E/p = c = constant$ has been known for long. It is an intrinsic part of modern physics since the Maxwell equations. In 1985 and 1988 I showed that this proportionality between „energy" and momentum is also at the heart of Isaac Newton's natural philosophy and theory of motion. There $E = pc$ represents Newton's „inertial force" (materiae vis insita; Principia, definition III; see my essay „Inertia the Innate Force of Matter" [6]). This force as an entity in itself is unknown in „classical" analytical mechanics, because after Newton's death 1727 it was dismissed and banned at will from science, in favour of only „inertia" as an intrinsic property of matter (Immanuel Kant, 1786 [7]).

Now and then it is claimed that $E/p = c$ would only hold for massless particles (photons), while for massive particles (electrons) $E = p^2/2m$ would result from experiments. This assertion is not true. The Heisenberg relations, implying the relation $E/p = c$ (as shown above), are not restricted to just photons. These relations hold for massive particles as well. Moreover, it is not true that $E = p^2/2m$ would result from experiments. As a matter of fact it is a purely theoretical construct developed by G. W. Leibniz and published as early as 1686, as will be shown in the next paragraph. Whenever this algorithm seems to appear in an experiment this is only due to the fact that *it is simply presupposed without proof*; consequently the alleged demonstration is invalid, since it rests on a logical error, that is, a *petitio principii* („begging the question"). A most prominent example is Einstein's 1905 explanation of the photoelectric effect. There he a priori introduced the hypothetical kinetic energy of the generated electrons, $E = p^2/2m = mv^2/2$, to correspond with the energy $E = pc = hf$ of the incident light, erroneously believing that both concepts (in Einstein's case: hf and $mv^2/2$) would be equivalent.

I should insert here in favour of Einstein that he in 1917 published a paper „The Quantum Theory of Radiation" which implicitly corrects the said error (but apparently unrecognized by Einstein). In this 1917 paper Einstein states that „If a beam of radiation has the effect that a molecule on which it is incident absorbs or emits an amount of energy hf in the form of radiation by means of an elementary process, then the momentum hf/c is always transferred to the molecule" [8]. Of course this $p = hf/c$ for „momentum of the molecule" immediately yields $pc = hf = E$ for „energy of the molecule" – that is, for the „energy" $E = pc = (mv)c$ [9] on the side of matter that corresponds with $E = hf$ on the side of radiation!

It was, by the way, Louis de Broglie who, rightly assuming a matter-wave *analogy*, in 1924 proposed to measure not only the momentum of photons but also that of electrons according to $p = h/\lambda$ [10], entailing E = pc, or E/p = c, as has been shown above. This proposal, however, was to no effect at de Broglie's time. The leading scientists continued to use the $E = p^2/2m$ formula.

5. In Schrödinger's „wave mechanics" the algorithm $E = p^2/2m$ is also hypothetically presupposed as being true, and for waves and particles alike. The Schrödinger equation basically consists of this concept of kinetic energy (the Hamiltonian „Gesamtenergie" H) to characterize a system's „energy" in general. Since the time when Erwin Schrödinger made it the foundation of his theory, this algorithm has been understood as one of the pillars of quantum mechanics [11]. Never has its validity been analyzed so far. So I shall do this analysis in the next paragraph.

II

1. If a body moves in a straight line in space from A to B to C through equal distances AB and BC, and the body's velocity is supposed to increase in proportion to the spaces covered, the velocity acquired in B will be = AB/t, and the velocity acquired in C will be AC/t = 2AB/t. Obviously the time, t, which the body consumes while moving from A to B is equal to the time required to go from B to C, and also equal to the total time of traveling from A to C. So it seems that the body would exist at different places in space, B and C, at one and the same time, t, or simultaneously, that is. In other words, the body would travel through distances in space *instantaneously,* meaning „without consuming time". This apparently mystical and weird effect, however, is only due to the chosen initial condition „velocity increasing *in proportion to space*". If instead we choose the condition „velocity increasing *in proportion to time*", we arrive at Galileo's rational law of free fall [12]. So it is the very idea that velocity might increase in proportion to space which leads into absurdities of timelessness such as instantaneous actions at a distance, or, an object apparently existing at different places in space at the same time. Evidently it makes no sense to presuppose that whatever is happening in time could be calculated in proportion to space only, that is, by means of a space integral.

2. This unrealistic presupposition, however, characterizes quantum mechanics insofar as this theory, represented by the Schrödinger equation, mainly consists in calculating energy states of particles and systems as energy states of a wave function. The energy calculated is kinetic energy, $E = p^2/2m$. It is in classical mechanics defined as the quantity of „work" a moving material body gathers while traveling through a certain distance in space. Accordingly this quantity is calculated by means of space integrals, or path integrals only, ignoring the time of generation of the energy states.

The modern „path integral" replaces what had been expressed as „proportional to space" at the time when kinetic energy was conceived. This happened 337 years ago, when Gottfried Wilhelm Leibniz proposed to measure the „force" of a body in proportion to the space covered while moving. In 1686 Leibniz published a short paper meant to demonstrate the „true measure" of the concept of force by measuring the distances which a body would cover while falling. From Galileo's investigation of the law of free fall (1638) Leibniz took that there is a squared relation between distance, or height of fall, and velocity. So he inferred that the force, hypothetically presupposed to be proportional to that height, must stand in a squared relation to the falling body's velocity [13]. From here comes the term „velocity squared" which characterizes the concept of kinetic energy *as a scalar* to this day.

Leibniz, however, had misunderstood Galileo; he had ignored that Galileo had rightly dismissed the idea to measure the falling body's velocity *in proportion to space.* Galileo demonstrated in detail that with this measure one would find the moving body to occupy different places at the same time – which he rightly called absurd. As a consequence he chose the alternative, that is, to measure the velocity of motion *in proportion not to space but to time.* And this is Galileo's true natural law of free fall.

3. A short but informative historical remark: Leibniz's 1686 paper initiated a long controversy among scientists concerning the measure of „living force", as Leibniz had called his concept: the „vis viva controversy". In this context Isaac Newton and his amanuensis Samuel Clarke in 1715 criticized Leibniz's concept as „a wonderfully philosophical error". Their point was that Leibniz's idea to conceive the generation of motion and its cause „force" (later: energy) in proportion to space meant to ignore the time of generation, or in other words, to ignore the natural law that *nothing happens but in time*. In 1728 Clarke published in the Royal Society's Philosophical Transactions a „Letter to Benjamin Hoadly" summing up the arguments [14]. I will quote from it in paragraph III.

Leibniz's concept nevertheless survived. When after Newton's death (1727) the so-called analytical mechanics was developed by d'Alembert, Euler and Lagrange, Leibniz's „living force" gained even a prominent place in the new theory (the later „classical mechanics"), now under the new name „energy" (kinetic and potential). Every physicist knows it as the product of force and distance, or the space integral of force. In the 1830es William Rowan Hamilton developed a new mathematical method of mechanics which uses the Leibnizian concept of energy as a basis and describes the total energy of a system under the symbol H as „Hamilton function".

III

1. Is quantum physics (represented by the Schrödinger equation) a comprehensive theory that opens a window to a new reality? Schrödinger's equation was conceived presupposing the Hamiltonian H, implying the concept of kinetic energy. As has been shown above, this concept emerges as a space integral of force. Now, since a space integral is not a time integral, to calculate the kinetic energy E (or the Hamiltonian H) of a moving object by integrating over the space described just means to calculate the object's timeless states in space: It does not consider the time it takes the object to describe a distance in space, or the object's velocity. Therefore, the Schrödinger equation is not an equation of motion. It does not describe a trajectory in time and space.

As has also been shown, the „classical" *scalar* concept of kinetic energy (proportional to the momentum p squared) is not compatible with the *vector* quantity $E/p = c$ (E being proportional to p only) that is implicitly given with the Heisenberg relations. Consequently, applications of Schrödinger's equation which seem to demonstrate instantaneous actions at a distance and other phenomena of timelessness are due to Schrödinger's presupposing as an unquestioned hypothesis the mistaken algorithm „kinetic energy". This basic error alone inevitably implies and entails these weird and mystical consequences of quantum mechanics. It should be corrected by replacing the kinetic energy term with the true quantummechanical energy $E = pc$. This procedure, by the way, also solves the well-known problems concerning the validity of the Heisenberg relation (2). For example, in the past the question has raised a huge amount of mathematical papers whether or not this time-energy relation holds true. Actually in all these papers, however, the problem has never been understood as one of the energy term $E = p^2/2m$ which has always been presupposed as undoubtedly true.

To realize the just demonstrated shortcomings and the simple means to correct them helps to understand that there is no „new reality" revealed by the Schrödinger equation. There is just the basic law of proportionality of cause and effect, $E \sim p$. There is no „natural constant h", and there is no intrinsic „indeterminacy" of operators. To sum it up: There is no „Neue Welt der Quantenphysik" (contrary to the subtitle of the 2022 Nobel Laureate Anton Zeilinger's 2003 book „Einsteins Schleier" [15]).

2. This is not for the first time that an independent analysis of the scientific and philosophical work of most distinguished scholars brings to light something that could well be called a „proton pseudos", a

basic first error, contaminating all later theoretical developments. If this happens it is always due to ignorance, in our case ignorance of geometric proportion theory, and due to blind belief in authority, in our case the authority of the famous founders of quantum mechanics. As an argument against belief in the authority of eminent scholars, Nobel Laureates included, I quote part of Samuel Clarke's 1728 letter to Benjamin Hoadly F.R.S, published in the Philosophical Transactions of the Royal Society for 1727 and 1728. The letter begins as follows:

„Sir,

It has often been observed in general, that Learning does not give Men Understanding; and that the absurdest things in the World have been asserted and maintained, by Persons whose Education and Studies should seem to have furnish'd them with the greatest Extent of Science.

That Knowledge in many Languages and Terms of Art, and in the History of Opinions and Romantick Hypotheses of Philosophers, should sometimes be of no Effect in correcting Man's Judgement, is not too much to be wonder'd at. But that in Mathematicks themselves, which are a real science, and founded in the necessary Nature of Things, men of very great Abilities in abstract Computations, when they come to apply those Computations to the Nature of Things, should persist in maintaining the most palpable Absurdities, and in refusing to see some of the most evident and obvious Truths, is very strange.

An extraordinary instant of this we have had of late Years in the very eminent Mathematicians, Mr. Leibnitz, Mr. Herman, Mr. S'Gravesande, and Mr. Bernoulli, who (in order to raise a Dust of opposition against Sir Isaac Newton's Philosophy; the Glory of which is the Application of abstract Mathematics to the real Phenomena of Nature) have for some Years insisted with great Eagerness, upon a principle which subverts all Science, and which may easily be made appear (even to an ordinary capacity) to be contrary to the necessary and essential Nature of Things.

What they contend for, is, That the Force of any Body in Motion, is proportional, not to its velocity, but to the Square of its Velocity.

The Absurdity of which Notion, I shall first make appear, and then shew what it is that has led these Gentlemen into Error." (end of quote).

I think the time has come to admit that Samuel Clarke, about 300 years ago, was right.

Today we can see clearly that a realistic quantum mechanics just requires to dismiss the mistaken Leibnizian concept of kinetic energy, and replace it with the true proportionality between force, or energy, and velocity, or momentum p *only*. Thus showing the energy-momentum proportion $E/p = c$ (proportionality of cause E and effect p) to hold universally reveals this „electromagnetic" formula (Maxwell; Poynting) *as a universal causal law*, valid for material particle motion and for wave propagation as well, as it had implicitly been proposed already by Louis de Broglie in 1924 [16].

Literature:

[1] Max Jammer, The Philosophy of Quantum Mechanics, Wiley, New York etc., 1974. On p. 86-94 the reader finds a representation of Bohr's Como lecture, on p. 93 the equation (5) as an equation of products $\Delta t \times \Delta E = \Delta x \times \Delta p = h$. On pp. 136-156 discussions of „the time-energy relation".

[2] Isaac Newton, Mathematische Grundlagen der Naturphilosophie, Ed Dellian Hrsg., Meiner, Hamburg, 1988, Auswahlausgabe (Philos. Bibliothek Nr. 394). Further editions appeared in the course of time, in Academia Verlag St. Augustin. Each edition contains a separate new introduction. The latest dates from 2014. On p. 25/6 the reader finds the Heisenberg relations as a quaternary

proportion, resulting in E/p = c, which formula is demonstrated to be already a part of Galileo's 1638 theory of material (particle) motion.

[3] Ed Dellian, Does Quantum Mechanics Imply the Concept of Impetus? Physics Essays vol. 3 no. 4, 1990, p. 365. The paper shows the reason why Schrödinger's theory appears to be noncausal and nonlocal, and it demonstrates the energy concept E = (mv)c for matter.

[4] Max Born, Die Relativitätstheorie Einsteins, 6. Aufl., Hrsg. Jürgen Ehlers und Markus Pössel, Springer, Berlin etc., 2001. On p. 244/5 Einstein's nonrelativistic derivation of $E = mc^2$, exhibiting the equation mv = E/c (p = E/c, or E = p x c), which Einstein calls „Impulsgleichung", as an integral part of the demonstration. On p. 244 the author Max Born correctly refers to John Henry Poynting (1884), and to the theory of radiation pressure, again presenting for matter (!) the „Impulsgleichung" p = E/c.

[5] Werner Heisenberg, Physikalische Prinzipien der Quantentheorie, Bibliographisches Institut, Mannheim etc., 1958. On p. 93 under „Partikelbild der Strahlung" one finds the equation E = c x p.

[6] Ed Dellian, Inertia, The Innate Force of Matter, in: P. B. Scheurer and G. Debrock (eds.), Newton's Scientific and Philosophical Legacy, Arch, Int. d'Hist. des Idées 123, Kluwer, Dordrecht etc., 1988, pp. 227-237. On p. 231 the reader finds the eq. (3) E = (mv) x c, which is identical with E = pc, of course.

[7] Immanuel Kant, Metaphysische Anfangsgründe der Naturwissenschaft, Riga 1786. Drittes Hauptstück „Mechanik", Lehrsatz 4 Anmerkung 2: „Die Benennung der Trägheitskraft (vis inertiae) muss also unerachtet des berühmten Namens ihres Urhebers aus der Naturwissenschaft gänzlich weggeschafft werden". Kant here replaces Newton's inertial force with only „inertia" as a quality of matter. This idea became a basic concept of modern physics, where Newton's *quantity* „mass" is misinterpreted and understood in Kant's *qualitative sense*.

[8] Albert Einstein, The Quantum Theory of Radiation, Physikalische Zeitschr. 18 (1917), 121. The quoted passage can be found in Einstein's „Results" at the end of his paper.

[9] Ed Dellian, Short Demonstration of the Energy Concept E = (mv)c as a Desideratum of Microphysics. This demonstration was published as a poster in 1987, Vienna, at the Workshop „Matter Wave Interferometry", 14-16 Sept 1987, „On the Occasion of the 100th Anniversary of E. Schrödinger's Birth". See http://inis.iaea.org/Collection/NCLCollectionStore/_Public/20/000/20000018, pp.6, 29.

[10] Louis de Broglie, Recherches sur la théorie des quanta, Annales de Physique, 10e Série, Tome III, Janvier-Février 1925. De Broglie's proposal of an analogy between matter wave and particle yields for matter the momentum p = h/λ which inevitably entails (again for matter) the energy term E = pc as has been demonstrated above.

11] Hagen Kleinert, Path Integrals, World Scientific, Singapore etc., 1995. Chapter I „Fundamentals" shows the foundation of quantum mechanics in „classical" mechanics to be basically the Hamiltonian H which already appears on p. 3. Kleinert's book is representative for all other scientific books on the foundation of quantum mechanics. Nowhere does the author mention, much less does he criticise the meaning of kinetic energy as the basic content of the Hamiltonian.

[12] Galileo Galilei, Discorsi (Unterredungen und mathematische Beweisführungen zu zwei neuen Wissensgebieten), Ed Dellian Hrsg., Meiner, Hamburg, 2015 (Philosophische Bibliothek Nr. 678). On p. 197/8 the reader finds Galileo's arguments against the idea that the velocity of a moving body could increase *in proportion to space*. My introduction demonstrates the proportionality constant c (dimensions space over time) and the proportionality of „force" and momentum (as cause and effect) to be an indispensable integral part of Galileo's mechanics.

[13] Samuel Clarke, Der Briefwechsel mit G. W. Leibniz von 1715/1716, Ed Dellian Hrsg., Felix Meiner Verlag Hamburg, 1990 (Philosophische Bibliothek Nr. 423). The edition contains in Appendices II-IV Leibniz's 1686 paper with a commentary, a detailed criticism of Leibniz's concept of „living force“ or „energy“, and a German translation of Samuel Clarke's 1728 letter to Benjamin Hoadly.

[14] see ref. [13].

[15] Anton Zeilinger, Einsteins Schleier, Die neue Welt der Quantenphysik, C. H. Beck, München, 2003. The author, Nobel Laureate 2022, writes on p. 180: „Manchmal wird argumentiert, dass – da die Quantenmechanik zu ihrer eigenen Rettung hinzugezogen wird – man sich in der Argumentation sozusagen im Kreis bewege. Aber gerade so muss es ja sein. Die Quantenphysik ist eine umfassende Theorie, deren Gültigkeitsbereich man nicht irgendwo einschränken darf. In dem Moment, wo man dies täte, beginge man einen entscheidenden Fehler“. – As we see, Zeilinger makes the „petitio principii“, that is, a logical mistake *par excellence*, the foundation of quantum mechanics, calling the absurd result „umfassende Theorie“, that is, a comprehensive theory of physics.

[16] see ref. [10].