Significant Facts Revealed by the EPR Paradox and Bell's Theorem

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The paradox formulated by Einstein, Podolsky and Rosen aimed to prove incomplete the description of reality provided by wave functions and the need for additional (hidden) variables, which restore causality and locality in quantum physics. Bell's theorem followed and seemed to prove that unlike the Copenhagen version of Quantum Mechanics, any theory based on hidden variables predicts incorrect outcomes for quantum entanglements. As a result, physicists drew the following conclusions: 1) all deterministic versions of Quantum Mechanics are inherently incorrect 2) quantum particles interact instantaneously across any distance and 3) Quantum Mechanics and the Theory of Relativity are incompatible. But Bell implicitly assumed locality means the angular-momentum of one entangled particle cannot be exactly predicted based on the measurement of the other particle. Simple and unequivocal experiments show Bell's assumption is invalid. Therefore, all three conclusions are wrong. Classical Mechanics, which is strictly deterministic and local, and Quantum Mechanics will merge seamlessly after the revision of the later. Quantum entanglements allow circumventing the uncertainty principle. These are the significant facts revealed by the EPR paradox and Bell's theorem not previous assertions. The overhaul of Quantum Mechanics has to start with three crucial corrections: 1) the assumption that a quantum object exists in a superposition of states must be replaced with the ensemble interpretation of a wave function, 2) the energy of deformation must be included in the Hamiltonian of quantum objects and 3) the term "particle" should be outlawed.

1. Nomenclature

$\mathbf{a}$	unit vector indicating the 1st detector axis
$\mathbf{b}$	unit vector indicating the 2nd detector axis
$c_{i,j}$	coefficients of state function
h	scale constant
$\mathbf{K}$	angular momentum
N	normalization factor
P	expectation value of singlet
p	probability
$\mathbf{S}_x, \mathbf{S}_y, \mathbf{S}_z$	Pauli's spin matrices
α	angle between detectors
Φ	angle between 1st first spin and 1st detector axes
$\varphi_1, \theta_1, \Psi_1$	Euler angles of 1st spin axis
$\boldsymbol{\sigma}_1, \boldsymbol{\sigma}_2$	spin vectors
ψ	wave function

2. The Importance of Quantum Entanglements

The quantum paradigm has challenged not only the basis of physics but also the traditional view of reality. The quantum paradigm denies any objective reality besides measurements interpreted according to an esoteric formalism. The final validation or rejection of this new paradigm (not to mention breakthrough applications such as quantum cryptography and quantum computing) hinges on experiments involving quantum entanglements.

For these reasons, quantum entanglements are a hot topic of research. Thousands and thousands of books and articles have been written on this subject, yet nobody has been able to explain the physical mechanism of quantum entanglements. Nevertheless, the mechanism is surprisingly simple. The goals of this article are to clearly explain the physical mechanism of all entanglements and to end the debate on the nature of reality and the proper basis of physics.

3. Physical Reality According to the Copenhagen School of Quantum Mechanics

According to experiments performed up to date, it seems impossible to simultaneously know the values of all properties of a quantum system. Properties that cannot be known with precision must be described by probabilities. From these observations, the Copenhagen school of Quantum Mechanics concludes that a deterministic description is not possible and therefore a wave-function provides a complete description of a system. As stated by Einstein, Podolsky and Rosen [1]: "If the operators corresponding to two physical quantities, say A and B, do not commute, that is AB≠BA, then the precise knowledge of one of them precludes such a knowledge of the other. Furthermore, any attempt to determine the latter experimentally will alter the state of the system in such a way as to destroy the knowledge of the first" (for this reason, Pauli's matrices do not commute). There are two possible explanations for this loss of knowledge: 1) equipment limitations, which may be lifted by future advances in science and technology, 2) the ontology of quantum systems, i.e., if A is known then B has no physical reality and vice versa. The Copenhagen school embraced the second explanation and claimed that physical quantities have no physical reality [1] - an extraordinary claim based on ordinary evidence. This is the paradoxical end result of the positivist quest to firmly ground science in reality by rooting out any concept that cannot be experimentally confirmed. At first glance, this quest may seem logical. But the Copenhagen school implicitly considered only experiments performed with instruments available when a theory was conceived. According to the Copenhagen school, ancient philosophers who claimed that every object is a mixture of air, fire, earth and water were true scientist and all those who dared to express a different opinion were crackpots because only air, fire, earth and water can be observed with ancient instruments.

4. The EPR Argument

In a landmark paper published in 1935 [1], Einstein, Podolsky and Rosen attempted to show that a wave function cannot be a complete description of reality. "In a complete theory there is an element corresponding to each element of reality. A sufficient condition for the reality of a physical quantity is the possibility of predicting it with certainty without perturbing the system." [1]. In order to prove the EPR thesis; Bohm and Aharonov advocated the following example [2]: Consider a pair of particles with spin one-half, which somehow were initially entangled forming a singlet spin state and then moved freely in opposite directions. The particle spins are $\boldsymbol{\sigma}_1$ and $\boldsymbol{\sigma}_2$. Selected components of particle spins can be measured using for example magnets or polarized-light detectors. If the measurement of component $\boldsymbol{\sigma}_1 \bullet \mathbf{a}$, where $\mathbf{a}$ is a unit vector defining the orientation of axis a, yields +1, then according to Quantum Mechanics the measured value of $\boldsymbol{\sigma}_2 \bullet \mathbf{a}$ must be -1 and vice versa. If these measurements are made at very distant locations, the orientation of one measuring instruments would not influence the result provided by the other. Because the result of measuring any component of $\boldsymbol{\sigma}_2$ can be predicted in advance by measuring the same component of $\boldsymbol{\sigma}_1$ the result of any such measurement must be predetermined. The initial wave function of the singlet does not determine the result of any individual measurement. Therefore, the above mentioned predetermination indicates the possibility of a more complete state specification.

5. Perceived Loophole in the EPR Argument

Trying to refute the EPR argument, Bohr claimed there is an ambiguity in the EPR assumptions [3]. In essence, Bohr suggested that entangled particles may instantaneously interact at any distance. As soon as the spin of a particle is measured, the wave function of the other particle collapses due to some instantaneous interaction at any distance (a "spooky" interaction as Einstein said, a non-local phenomenon), which according to both the special and general theory of relativity is impossible. If Bohr is right; the Copenhagen version of Quantum Mechanics (henceforth simply called Quantum Mechanics) and relativity are incompatible. In order to reject the idea of a hidden parameter, Bohr postulated the existence of a whole new type of hidden interactions, an idea contradicted by widely accepted theories of physics and all experiments except quantum entanglements. This is indeed a fine example of burning the village to the ground in order to save it.

6. A Review of Bell's Conclusions

The statistical predictions of Quantum Mechanics have been confirmed by numerous experiments involving quantum entanglements [4-7]. Therefore, the predictions of hidden variable theories should agree with the statistical predictions of Quantum Mechanics. In 1964, John S Bell published a paper on the EPR paradox [8], which aimed to prove that no hidden variable theory can be compatible with the predictions of Quantum Mechanics, ergo all deterministic versions of Quantum Mechanics have been disproved by experimental results.

To accept Bell's argument at face value means to conclude that

1. Quantum objects are ruled by hazard.
2. Quantum Mechanics and relativity are incompatible.

Should we nevertheless conclude that Bohr won the dispute with Einstein? Let us focus on the assumptions made by Bell: "We wish to avoid" the situation where "the results of measurements with one magnet depend on the setting of the distant magnet" (the second magnet) [8]. Bell specifically states "there is no difficulty in reproducing the quantum mechanical correlation" if the measurement on one magnet depends on the setting of the distant magnet. With this sentence, Bell offhandedly dismissed deterministic versions of Quantum Mechanics, which, in his own words "have no difficulty in reproducing the quantum mechanical correlation". Therefore, Bell and all other scientists interested in quantum entanglements blithely ignored Classical Mechanics, which is the archetypal deterministic theory and is local. These scientists also ignored the Correspondence Principle [9], which states that Quantum Mechanics must reproduce the results of Classical Mechanics when applied to large objects or else be rejected as incorrect. Therefore, Classical and Quantum Mechanics are expected to predict the same entanglement correlation. Why was Classical Mechanics ignored? Because Bell relied on yet another assumption, one implicit and buried so deep that it was overlooked by everybody. The buried assumption can be spelled out as follows: the results of one measurement can be predicted based on the other only if one measurement can influence the other. As will be shown in Section 7, this assumption violates the law of angular-momentum conservation. Therefore, this implicit assumption is the Achilles' heel of Bell's demonstration and of all the follow up work on quantum entanglements.

Section 7 presents an experiment with common objects and instruments, which can be easily reproduced. The experiment demonstrates that Classical Mechanics and Quantum Mechanics predict exactly the same correlation for entangled particles but cannot agree on the cause of this correlation.

7. An Experiment with Entangled Objects

Scale models are widely used by engineers to solve a wide range of practical problems [10, 11]. Therefore, consider a possible model of quantum entanglements - a pair of gears mounted with bearings on shafts, as shown in Fig. 1. Sections 7 and 8 prove this model is similar to quantum entanglements (scale models are useful only when similar with the original system).

At time $t = 0$, one gear is forced to rotate clockwise, for example. Because the gears are "entangled", the other gear begins to rotate counter-clockwise. The pair of gears forms a "singlet" with null angular-momentum. Both gears can be made to resemble half spin particles because the speed of rotation, angular momentum units and sense of rotation can be chosen as desired. The gear spins are labeled $\boldsymbol{\sigma}_1$ and $\boldsymbol{\sigma}_2$.

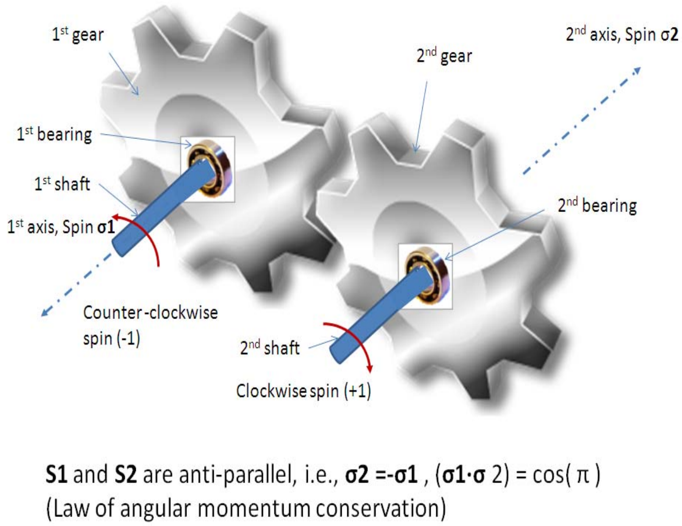

Fig. 1. Paired gears forming a singlet at time t=0

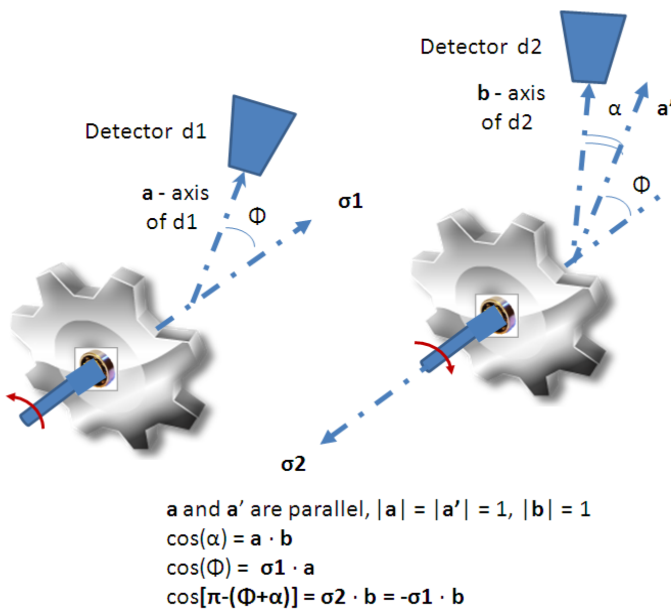

Fig. 2. Measurements of paired gears forming a singlet

After actuation, the gears are displaced by translation in arbitrary directions. Detector *d1* measures the component of spin $\boldsymbol{\sigma}_1$ on arbitrary direction **a**, see Fig. 2. Detector *d2* measures the component of spin $\boldsymbol{\sigma}_2$ on arbitrary direction **b.** In order to satisfy the complementarity principle, the gear axis of rotation is forcibly aligned with the detector axis during measurement

The gears interact only at time $t=0$. There is no subsequent interaction between gears; neither normal nor spooky. The detectors do not interact at all. At initial time, the first gear could be forced to rotate either clockwise or counter-clockwise and the axis of $\boldsymbol{\sigma}_1$ is randomly selected. As a result, the detectors operators know only one thing in advance: the probability, *p*, that a gear will rotate clockwise (positive spin) or counter-clockwise (negative spin) around some arbitrary axis. Let this probability be:

$$p=\frac{1}{2} \tag{1}$$

Nevertheless, the operators can always predict the result of one spin measurement based on the result of the other because the singlet angular-momentum is conserved. As seen from Fig. 1, the two axes of rotation are anti-parallel and remain anti-parallel until measurement because both gears are displaced by translation - no torque is applied on gears during displacement. Therefore, $\boldsymbol{\sigma}_2=-\boldsymbol{\sigma}_1$ before measurements.

If detector *d1* measures $\boldsymbol{\sigma}_1\bullet\mathbf{a}$ then the measurement of $\boldsymbol{\sigma}_2\bullet\mathbf{a}$ is superfluous, because according to the law of angular angular-momentum conservation

$$\boldsymbol{\sigma}_2\bullet\mathbf{a}=-\boldsymbol{\sigma}_1\bullet\mathbf{a} \tag{2}$$

The experiment is repeated with different spin and detector axes. The expectation value of the product of components $\boldsymbol{\sigma}_1\bullet\mathbf{a}$ and $\boldsymbol{\sigma}_2\bullet\mathbf{b}$, can be determined both experimentally and analytically. Analytically, the expectation value $P(\mathbf{a},\mathbf{b})$ is calculated as follows:

$$\begin{aligned}P(\mathbf{a},\mathbf{b})&=N\int_0^{\pi}(\boldsymbol{\sigma}_1\bullet\mathbf{a})(\boldsymbol{\sigma}_2\bullet\mathbf{b})\\&=N\int_0^{\pi}\cos\Phi\cos\left[\pi-(\alpha+\varphi)\right]\end{aligned} \tag{3}$$

where N is a normalization constant. N is determined from the following condition: the same result is expected when the same parameter is measured twice. This means the expectation value is 1 when the same component of spin is measured twice, for example, when $\boldsymbol{\sigma}_1\bullet\mathbf{a}$ is measured twice. Therefore

$$\begin{aligned}1&=N\int_0^{\pi}(\boldsymbol{\sigma}_1\bullet\mathbf{a})(\boldsymbol{\sigma}_1\bullet\mathbf{a})d\Phi=N\int_0^{\pi}\cos^2\Phi\,d\Phi\\&=N\int_0^{\pi}\frac{d\Phi}{2}+N\int_0^{\pi}\cos(2\Phi)\frac{d\Phi}{2}\\&=N\frac{\pi}{2}+\frac{N}{4}\int_0^{2\pi}\cos\Phi'\,d\Phi'=N\frac{\pi}{2}+0=N\frac{\pi}{2}\end{aligned} \tag{4}$$

From Eq. (4), $N=\dfrac{2}{\pi}$. As a result, Eq. (3) can be written as follows

$$\begin{aligned}P(\mathbf{a},\mathbf{b})&=\frac{2}{\pi}\int_0^{\pi}\cos\Phi\cdot\cos\left[\pi-(\alpha+\Phi)\right]d\Phi\\&=-\frac{2}{\pi}\int_0^{\pi}\cos\Phi\cdot\cos(\alpha+\Phi)\,d\Phi\\&=-\frac{2}{\pi}\int_0^{\pi}\cos^2\Phi\cdot\cos\alpha\,d\Phi+\frac{2}{\pi}\int_0^{\pi}\sin\alpha\cdot\cos\Phi\cdot\sin\Phi\,d\Phi\\&=-\frac{2\cos\alpha}{\pi}\int_0^{\pi}\frac{d\Phi}{2}-\frac{2\cos\alpha}{\pi}\int_0^{\pi}\cos(2\Phi)\frac{d\Phi}{2}+\frac{\sin\alpha}{\pi}\int_0^{\pi}\sin(2\Phi)\,d\Phi\\&=-\frac{2\cos\alpha}{\pi}\cdot\frac{\pi}{2}-0+0\end{aligned} \tag{5}$$

Therefore $$P(\mathbf{a},\mathbf{b})=-\cos\alpha=-\mathbf{a}\bullet\mathbf{b} \tag{6}$$

Being based solely on the law of angular-momentum conservation, this result remains unchanged if gears are replaced with spinning objects of any other type and/or size.

Operators may choose any initial axes, and may realign one detector or both while gears are in transit without affecting Eq. (2). The order of $\boldsymbol{\sigma}_1 \bullet \mathbf{a}$ and $\boldsymbol{\sigma}_2 \bullet \mathbf{b}$ measurements is also irrelevant. As discussed above, the gear measurements are invasive. Therefore, this model violates Leggett's inequality [12].

According to Quantum Mechanics and experimental results - see Eq. (3) from Bell's original paper [8] - the expectation value for a singlet state formed by a pair of quantum "particles" with half spin is:

$$\langle \boldsymbol{\sigma}_1 \bullet \mathbf{a} | \boldsymbol{\sigma}_2 \bullet \mathbf{b} \rangle = -\mathbf{a} \bullet \mathbf{b} \tag{7}$$

Eqs. (6) and (7) are equivalent. Conclusion: according to Classical Mechanics, the scale model described above is similar to quantum entanglements including before-before experiments.

The equivalence of Eqs. (6) and (7) demonstrates that Classical and Quantum Mechanics provide the same expectation value, a value validated by countless experiments. As mentioned, Classical Mechanics is the archetype of deterministic theories. Therefore, the claim that no deterministic version can reproduce the expectation value provided by the Copenhagen version of Quantum Mechanics is invalid.

Without understanding his own paper, Bell has proven that Classical Mechanics is the only theory that agrees with quantum entanglements and does not involve spooky interactions (Quantum Mechanics is not local). Therefore, a version of Quantum Mechanics that would be a faithful extension of Classical Mechanics would agree with all entanglement experiments and would be local. Such a version has already been proposed by the author [13, 14, 15]. Section 9 presents additional features of this version, which are relevant here.

8. Quantum Mechanics Validates the Model

The model validity has also to be proven by Quantum Mechanics. As mentioned in section 7, the observers using detectors d1 and d2 know only one thing in advance: eq. (1). As a result, these observers may define operators for the x, y and z spin components $(\mathbf{S}_x, \mathbf{S}_y, \mathbf{S}_z)$ using Pauli matrices:

$$\mathbf{S}_x = \frac{\mathbf{h}}{2}\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \quad \mathbf{S}_y = \frac{\mathbf{h}}{2}\begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix} \quad \mathbf{S}_z = \frac{\mathbf{h}}{2}\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} \tag{8}$$

where h is a scale constant. The eigenvectors of $(\mathbf{S}_x, \mathbf{S}_y, \mathbf{S}_z)$ are:

$$|x^+\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ 1 \end{bmatrix} \quad |y^+\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ i \end{bmatrix} \quad |z^+\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ 0 \end{bmatrix} \tag{9a}$$

$$|x^-\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ -1 \end{bmatrix} \quad |y^-\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ -i \end{bmatrix} \quad |z^-\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix} 0 \\ 1 \end{bmatrix} \tag{9b}$$

The above eigenvectors form the basis for $\boldsymbol{\sigma}_1$ and $\boldsymbol{\sigma}_2$. The wave function of a gear singlet ψ is given by:

$$|\psi\rangle \geq \sum_{i,j} c_{i,j} |i\rangle_{\boldsymbol{\sigma}_1} \otimes |j\rangle_{\boldsymbol{\sigma}_2} \tag{10}$$

where $c_{i,j}$ are state coefficients.

The composite state defined above is inseparable, i.e., entangled. When spin is measured with respect to a given axis (for example, the x-axis), the probability of obtaining the value $h/2$, $p_{h/2}$ is given by:

$$p_{h/2} = \left| \langle \psi | x^+ \rangle \right|^2 \tag{11}$$

The expectation value of $\boldsymbol{\sigma}_1 \bullet \mathbf{a}$ and $\boldsymbol{\sigma}_2 \bullet \mathbf{b}$ can now be recalculated using Quantum Mechanics. As specified in literature [8], the result is Eq. (7), which is equivalent to Eq. (6). The initial wave function ψ does not predetermine the result of any individual measurement. Nevertheless, experiments show the result of the second spin measurement can be predetermined from the first one. Therefore the two gears are linked by a spooky interaction. The complementarity principle has been enforced and Leggett inequality is violated. Therefore, the gear ensemble is a faithful model of quantum entanglements according to both Classical and Quantum Mechanics.

9. The Overhaul of Quantum Mechanics

The Correspondence Principle requires that Quantum Mechanics should give exactly the same results as Classical Mechanics when applied to a large scale system, for example to the gear ensemble. If these Quantum and Classical Mechanics results differ in any way, the former theory is proven invalid.

As shown in sections 7 and 8, Quantum and Classical Mechanics agree on eq. (6) and on Leggett's inequality but cannot agree any further. According to Classical Mechanics eq. (6) is just a trivial result of angular-momentum conservation, not an indication of spooky interactions and the $\boldsymbol{\sigma}_1 \bullet \mathbf{a}$ and $\boldsymbol{\sigma}_2 \bullet \mathbf{b}$ measurements appear incompatible only at first glance. As shown in section 10, these two measurements are compatible in fact. Therefore, Quantum Mechanics does not satisfy the Correspondence Principle.

There are other scenarios proving that Quantum Mechanics fails this test - the most famous being Schrodinger's cat. In fact Quantum Mechanics is designed to fail this test, because the result of combining Quantum Mechanics with the Correspondence Principle boils down to the following "theorem":

1. Hypothesis: nature does not obey deterministic laws.
2. Conclusion: nature obeys deterministic laws.

This ontological fault is the root cause of the crisis in quantum physics. What attempts were made to cope with this crisis? For more than half a century, physicists have claimed that nature is absurd and we have to live with this absurdity (Feynman), blithely ignored this crisis or doggedly investigated only one possible resolution. But there are two:

1. Assume that Quantum Mechanics is correct, and Classical Mechanics is just an approximation. Then Classical Mechanics has to be revised based on Quantum Mechanics.
2. Assume that Classical Mechanics is correct, and Quantum Mechanics is just an approximation. Then Quantum Mechanics has to be revised based on Classical Mechanics.

Because the second alternative was dismissed a priori, the "resolution" provided by quantum physicists is just an attempt to cover up the crisis under a mountain of math. A scientific investigation of this crisis begins with a careful examination of both alternatives and ends revealing two major errors embedded in the foundation of Quantum Mechanics.

The first error is explained but not justified by the history of Quantum Mechanics. Quantum Mechanics was conceived when "elementary particles" were considered to be the ultimate building blocks of matter. As a result, Quantum Mechanics defines the Hamiltonian of an "elementary particle" in an incorrect manner. Work must be exerted in order to pull apart or to squeeze together the components of the complex structures called "elementary particles". According to the law of energy conservation, this work is accumulated inside the "particle" as internal energy of deformation and is ignored by Quantum Mechanics [13, 14, 15]. Experiments performed while Quantum Mechanics was conceived proved that "elementary particles" are anything but elementary. For example, the interaction of a particle with an antiparticle leads to the formation of a photon, a photon can split into a "particle" and an "antiparticle", "particles" behave like waves, etc. Scientists have discovered quarks more than 30 years ago and now are trying to detect preons. Nevertheless, quantum physicists continue to rely on the wrong Hamiltonian.

The second error is the Copenhagen interpretation of the wave function. As discussed in Section 3, the Copenhagen school claims that a wave function provides a complete description of a system. This claim leads to some interesting "conclusions". Here are some of these "conclusions" that really stand out:

1. Beings can be both dead and alive at the same time (Schrodinger's cat)
2. Nature is absurd (Feynman)
3. Quantum particles interact instantaneously no matter how far apart through spooky tricks, or spookier - according to a recent paper, plain spooky tricks are not enough to explain the results of quantum entanglements [16]. Interactions outside space and time are supposed to be required.
4. Reality is not real until measured - by the way, it would be nice if physicists would explain why reality does not unravel between measurements.
5. Mono-block objects rotate clockwise and counter-clockwise at the same time.

All experiments reveal beings that are either dead or alive but not both at the same time. Measurements of a "particle" spin yield positive or negative values but not both at the same time. Measurements have always yielded a state, never a superposition of states. The core of Quantum Mechanics is the tenet that a wave-function provides a complete description of a system, which means a system exists in a superposition of states. This tenet has been contradicted by all state measurements. These facts demonstrate that the core of Quantum Mechanics is crackpot ideology buttressed by utter contempt for the results of all state measurements.

All objects regardless of size obey the laws of Classical Mechanics. Eq. (7) is just a trivial consequence of the law of angular-momentum conservation. Experiments with entangled objects have been performed for centuries and all revealed exactly the same result: experimental validation of the law of angular-momentum conservation - nothing more, nothing less. Nevertheless, based on the fashionable assumption that an object rotates clockwise and counterclockwise at the same time, physicists now claim completely different results: "proof" of spooky or spookier interactions. Physicists keep repeating exactly the same action (experiments with entangled objects) expecting wildly different results.

In principle, Classical Mechanics alone would provide a complete description of quantum systems, yet now and for the foreseeable future, physicists need to expect less i.e., to aim for an approximate description because quantum systems are chaotic. Such systems have to be described by a blend of Classical Mechanics and statistics. Statistics must provide a tool or tools for quantifying the state uncertainty. As shown again in section 8, the wave function is a tool for quantifying the state uncertainty – nothing more and nothing less (Note: the correlation between various factors such as kinetic and internal energy and state uncertainty exceeds the scope of this paper). The wave function collapse is just the collapse of uncertainty. This is the ensemble interpretation of the wave-function - the correct interpretation.

For the sake of beliefs rooted in positivism (such as "a wave function provides a complete description of a system" and "we have discovered all that can be discovered") quantum physicists ignore the correct interpretation of wave functions. Positivism is the root cause of the crisis in quantum physics not the inherent nature of quantum objects. This crisis will continue unabated for a long time until positivism will be rejected at last. Then Quantum Mechanics will be overhauled and transformed into the proper blend of Classical Mechanics and statistics. This overhaul should begin with the following three corrections:

1. The internal energy of deformation has to be included in the Hamiltonian of quantum objects.
2. The interpretation of wave function advocated by the Copenhagen school must be discarded and replaced with the ensemble interpretation.
3. Quantum experiments have revealed only quantum objects with complex structures not particles. The use of labels such as "elementary particle" and "quantum particle" should be strictly prohibited. The proper label is quantum object.

The overhauled Quantum Mechanics will be a faithful extension of Classical Mechanics. Therefore, the conflict between these two disciplines would simply vanish. Like Classical Mechanics, the new version of Quantum Mechanics will be strictly deterministic and local.

10. Beyond the Uncertainty Principle

The experiment described in section 7 reveals yet another violation of the Correspondence Principle, which deserves a detailed discussion. According to Classical Mechanics the measurement of $\boldsymbol{\sigma}_1 \bullet \mathbf{a}$ does not interfere with the measurement of -$\boldsymbol{\sigma}_2 \bullet \mathbf{b}$. Therefore, these measurements are compatible, i.e., one measurement does not invalidate the other. In addition,

$$-\boldsymbol{\sigma}_2 \bullet \mathbf{b} = \boldsymbol{\sigma}_1 \bullet \mathbf{b} \qquad (11)$$

(because $\boldsymbol{\sigma}_2 = -\boldsymbol{\sigma}_1$). In other words, to measure $-\boldsymbol{\sigma}_2 \bullet \mathbf{b}$ means to measure $\boldsymbol{\sigma}_1 \bullet \mathbf{b}$. This result means a measurement of $\boldsymbol{\sigma}_1 \bullet \mathbf{b}$ does not destroy the knowledge provided by the $\boldsymbol{\sigma}_1 \bullet \mathbf{a}$ measurement. According to experiments and Classical Mechanics, the $\boldsymbol{\sigma}_1 \bullet \mathbf{a}$ and $\boldsymbol{\sigma}_1 \bullet \mathbf{b}$ measurements are in fact compatible. Therefore, it is non-sense to claim that, "If the operators corresponding to two physical quantities, say *A* and *B*, do not commute, that is $AB \neq BA$, then the precise knowledge of one of them precludes such knowledge of the other. Furthermore, any attempt to determine the latter experimentally will alter the state of the system in such a way as to destroy the knowledge of the first". But Quantum Mechanics ignores these facts and raises the supposed incompatibility of measurements to the level of a "principle" – the Uncertainty Principle.

This disagreement between Classical and Quantum Mechanics on measurement compatibility is significant for three reasons:

1. Provides yet another proof that Quantum Mechanics violates the Correspondence Principle.
2. Provides a method for circumventing the Uncertainty Principle.
3. Demonstrates that the Uncertainty Principle is not based on facts. This "principle" is just another error caused by reliance on an incorrect theory.

11. A More Complete Description of a Singlet

Ironically, the more complete description of a singlet sought for so long by Bohm, Aharonov and other physicists interested in quantum entanglements has been available for centuries. An axis of rotation can be represented by the Euler axis and angle parametrization [16]. This representation depends on just three parameters: a set of Euler angles. A set of Euler angles also describes a singlet state. Assume $\boldsymbol{\sigma}_1$ is defined by the following Euler angles: φ_1, θ_1 and Ψ_1. Then, according to the law of angular momentum conservation, $\boldsymbol{\sigma}_2$ is defined by the following Euler angles: $\pi - \varphi_1$, $\pi - \theta_1$ and $\pi - \Psi_1$. All singlet angles have exact values. But these values are not known in advance because the singlet ensemble is chaotic. For this reason, another parameter is required in order to describe a singlet: as completely as possible today: the probability that the system is defined by φ_1, θ_1 and Ψ_1. This probability is determined experimentally. Therefore, a proper description of a singlet requires 4 parameters and is simpler than the Copenhagen description, which requires more parameters, see Eqs. (9) and (10). The quaternion representation [17] requires one more parameter than the Euler representation but causes fewer numerical errors. Therefore the quaternion representation is recommended.

12. Other Explanations of Entanglement

Some authors try to show that quantum entanglements involve a completely unexplained and downright magic link between consciousness and quantum measurements. This idea may interest some mystics, but has no place in a science publication.

Other authors try to include the singlet and detectors in a global wave function, invoke the multi-universe theory or are looking for some unspecified variables that are hidden deep below Planck's constant. The goal of these authors is to promote hidden-variable theories that do not permit to predict the result of one spin measurement based on the other, yet agree with eq. (7). Such convoluted theories lead to equations far more complicated than the law of angular-momentum conservation. It is virtually impossible to conceive a simpler explanation than the law of angular-momentum conservation, i.e., $\mathbf{K} = \text{const}$. For this reason, Occam's razor rules in favor of Classical Mechanics. History shows alternate "explanations" succeed only in making the crisis in quantum physics murkier and therefore more intractable. Therefore, these theories warrant no further attention.

13. Conclusion

Here are the significant facts revealed by the EPR paradox and Bell's theorem:

1. The Copenhagen version of Quantum Mechanics and all but one deterministic version fail decisive tests.
2. The only theory that agrees with the results of experiments involving quantum entanglements, satisfies Bell's and Leggett's tests and is local is Classical Mechanics.
3. Quantum entanglements allow experimenters to circumvent the uncertainty "principle".

These facts and previous work lead to the conclusion that Quantum Mechanics has to be revised starting with the following three corrections:

1. The internal energy of deformation has to be included in the Hamiltonian of quantum objects.
2. The interpretation of wave function advocated by the Copenhagen school must be discarded and replaced with the ensemble interpretation.
3. The use of labels such as "elementary particle" and "quantum particle" should be strictly prohibited. The proper label is quantum object.

This overhaul will transform Quantum Mechanics into a faithful extension of Classical Mechanics and therefore eliminate the conflict between these two disciplines. In addition, this new version of Quantum Mechanics and relativity will agree on locality because Classical Mechanics is local. This crisis in quantum physics would end. Any attempt to resolve this crisis in a different manner would backfire, i.e., would make the crisis more complex and more intractable.

Scale models of quantum systems are very useful. Such models provide important results, which cannot be obtained otherwise.

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