Coherence Tests of Physical Theories

Abstract

Textbooks show that the low-velocity limit of special relativity is compatible with nonrelativistic mechanics. Analogous relationships hold between general relativity and the Newtonian theory of gravitation, and between quantum mechanics and classical physics. This work shows that this approach can be extended and yield coherence tests of additional theories. It provides a few examples that show the effectiveness of this approach and demonstrate inconsistent points of some mainstream physical ideas. Furthermore, other well-established physical principles can be utilized for this end. Unfortunately, a scientific work that undertakes this assignment can hardly be found in the current mainstream literature. Several cases are discussed in detail. The results show inconsistencies of fundamental standard model theories, such as quantum chromodynamics and the electroweak theory. Inconsistencies are also proved for the Majorana neutrino and the Proca theory of a massive photon.

Keywords: Coherence tests, physical principles, quantum chromodynamics, the electroweak theory.

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1 Introduction

The current literature indicates that the correspondence principle determines relationships between several pairs of physical theories. Here, an appropriate limit of a given theory agrees with the results of a lower rank theory. Researchers who worked in the first half of the 20th century used these relationships for a support of the important new physical theories that have been created during that epoch. The cases that are pointed out below substantiate this claim.

The significance of the correspondence between quantum mechanics and classical physics was recognized in the early days of quantum mechanics and it is mentioned in many textbooks. Here are few quotations that illustrate this point. Dirac states: "Classical mechanics must therefore be a limiting case of quantum mechanics" (see [1], p. 84). Schiff says: “It is reasonable to expect the motion of a wave packet to agree with the motion of the corresponding classical particle...” (see [2], pp. 25, 26). Similarly, Landau and Lifshitz say: “Quantum mechanics contains classical mechanics in the form of a certain limiting case” (see [3], p. 19). Messiah says: “Quantum Theory must approach Classical Theory asymptotically in the limit of large quantum numbers” (see [4], p. 29).

The literature indicates that correspondence relationships also hold between other theories. For example, Einstein explains how Maxwellian electrodynamics yields expressions that agree with electrostatics in cases where the charges do not move (see [5], pp. 85-86). He also explains how General Relativity (GR) reduces to special relativity (SR) in the case of a weak gravitational field. Similarly, in the case of a weak gravitational field, GR reduces to the Newtonian gravitational laws (see [6], p. 265). Furthermore, it is well known that for low velocity, SR reduces to Newtonian mechanics (see e.g. [6], p. 49).

Rohrlich's book begins with a discussion of the significance of the correspondence principle (see [7], pp. 1-6). His discussion proves that correspondence relationships hold for quite a few pairs of physical theories. Due to historical reasons, the term *correspondence principle* refers to the relations between quantum mechanics and classical physics. The term *generalized correspondence principle* refers to any pair of theories where the correspondence relationships hold. (Herein, for brevity's sake, the term *correspondence* applies to any appropriate pair of theories.) Correspondence means that in every case, the appropriate limit of a higher rank theory must agree with the laws of a lower rank theory. The plain outcome of this issue is:

A lower rank theory imposes constraints on the appropriate limit of a higher rank theory. Such constraints can be used as a test for the validity of a given higher rank theory.

Obviously, a validity test is a vital element of any scientific endeavor. This issue indicates the importance of the above-mentioned examples that show cases where the higher rank theory satisfies the constraints of its lower rank theory. Several problems stem from the foregoing discussion:

P.1 Can the correspondence principle be applied as a coherence test of other theories?

P.2 Can other well-established physical principles be used in a coherence test of any given physical theory?

P.3 Can well-established theories be used in a coherence test of any given physical theory?

It turns out that a comprehensive discussion of these problems is too long, and it is unsuitable for an article in a journal [8]. Hence, the rest of this work mentions only several cases that illustrate the significance of a positive answer to these problems.

The system of units where $\hbar = c = 1$ is used. Relativistic expressions take the standard form. The metric is diagonal and its entries are $(1, -1, -1, -1)$.

An example of the application of the correspondence between quantum fields theory (QFT) and quantum mechanics is discussed in the second section. A fundamental principle of physics says that a physical theory must properly describe experimental results that belong to its domain of validity. The consequences of this issue are discussed in the third section. Maxwellian electrodynamics is an extremely successful theory. Implications of the Maxwellian theory are examined in the fourth section. The fifth section contains a discussion of the results. Concluding remarks compose the last section.

2 QFT and Quantum Mechanics

The first volume of Weinberg's QFT textbooks clearly states the correspondence relationships between this theory and quantum mechanics (see [9], p. 49):

> *"First, some good news: quantum field theory is based on the same quantum mechanics that was invented by Schroedinger, Heisenberg, Pauli, Born, and others in 1925-26, and has been used ever since in atomic, molecular, nuclear and condensed matter physics."*

An important property of quantum mechanics is that the quantum function $\psi(\boldsymbol{x},t)$ is a mathematically complex function. Indeed, assume that for every $(\boldsymbol{x},t)$, the function $\psi(\boldsymbol{x},t)$ is mathematically real. Let us examine the Schroedinger equation of a free particle

$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\triangle\psi. \tag{1}$$

The particle's mass of the denominator means that quantum mechanics is a theory of a massive particle. Furthermore, if ψ is mathematically real then the left-hand side of (1) is pure imaginary whereas its right-hand side is real. It means that in this case $\psi(\boldsymbol{x},t)$ vanishes identically. Thus, $\psi^*\psi\,\triangle V = 0$, which is the probability that the quantum particle exists at the infinitesimal volume $\triangle V$, means that the quantum particle does not exist at all. This contradiction proves that the quantum function $\psi(\boldsymbol{x},t)$ must be mathematically complex.

Conclusion: *The correspondence between QFT and quantum mechanics and the mathematically complex function* $\psi(\boldsymbol{x}, t)$ *of the latter prove that the mathematically real functions of the electroweak particle* Z*, the Mathematically real form of the Higgs boson, the Majorana neutrino, and the Proca theory of a massive photon, are wrong.*

The foregoing arguments demonstrate how powerful are physical principles that provide the basis for a coherence test of quantum theories. Here the correspondence principle is used. Applications of other tests are discussed below.

3 The significance of Experiments

This section discusses two aspects of the significance of experiments as elements of a coherence test in theoretical physics. One case analyzes some strong interactions experiments. The other case explains how experiments affect the general structure of physical theories.

Quantum Chromodynamics (QCD) is the theory of the Standard Model (SM) sector that pertains to strong interactions. A fundamental principle of physics says that a given physical theory should adequately explain the results of experiments that are carried out within its validity domain. Let us use this unquestionable principle and examine QCD and well-established properties of two kinds of high-energy proton scattering experiments.

A high-energy electron-proton (e-p) scattering demonstrates a deep inelastic effect. Indeed, “because of the finite size of the proton, the cross section for electron-proton elastic scattering decreases rapidly with energy. Consequently, high-energy e-p interactions are dominated by inelastic scattering processes where the proton breaks up” (see [10], p. 178).

A general scattering effect says that with the increase of energy (and momentum) of the colliding particles, the scattering process is affected by interactions that take place within a smaller volume that includes these particles. Indeed, ”to probe *small* *distances* you need *high energies*" (see [11], p. 6).

The high-energy e-p scattering shows important properties of the proton structure:

> The experiments are "explained by assuming that the underlying process in electron-proton inelastic scattering is the elastic scattering of electrons from pointlike spin-half constituent particles within the proton, namely the quarks" (see [10], p. 185).

Features of the energy-dependence of the e-p cross-section are listed below:

ep.A The inelastic e-p cross-section is compared to the Mott cross-section (see e.g. [10], p. 183), and the Mott cross-section decreases strongly with the increase of the experiment's energy (see e.g. [10], p. 165). Hence, the data prove that:

> *The inelastic e-p cross-section decreases strongly with the increase of energy.*

ep.B It is stated above that "high-energy e-p interactions are dominated by inelastic scattering processes". Hence,

> *With the increase of energy, the elastic e-p cross-section decreases much faster than the inelastic cross-section.*

Let us turn to the high-energy proton-proton (p-p) scattering experiments. QCD says that "the proton is found to be a complex dynamical system comprised of quarks, gluons and antiquarks" (see [10], p. 178). The experimental values of the energy

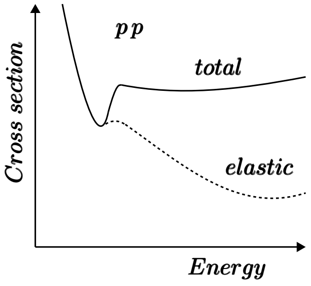

Figure 1: *Energy dependence of the total and the elastic proton-proton cross-section.*

dependence of the high energy elastic and total p-p cross-section are adequately documented [12], and their main properties are shown on fig. 1.

The following points explain why the data of this figure strongly disagree with the corresponding e-p data:

pp.A The inelastic e-p cross-section decreases strongly with the increase of energy. By contrast, at high energy, the inelastic p-p cross-section begins to rise. Therefore:

> *At high energy, the inelastic e-p cross-section and that of p-p cross-section show inherently different behavior.*

pp.B Unlike the negligible portion of the elastic e-p cross-section, the elastic p-p cross-section begins to increase with energy, and it takes more than 1/6 of the total cases. Hence,

> *At high energy, the elastic e-p cross-section is negligible. In contrast, at high energy, the elastic p-p cross-section increases with the increase of energy, and its relative portion begins to increase* [13].

This section presents well-known experimental data. It turns out that QCD cannot explain the results. The following points describe elements of the QCD inconsistencies.

QCD.1 QCD says that quarks, gluons, and antiquarks compose a proton. These particles carry color, and in strong interactions, color plays the role of charge in electromagnetic interactions.

QCD.2 Quarks are spin-1/2 pointlike particles. The QCD's gluons are analogous to photons, namely, they are pointlike particles.

QCD.3 The e-p scattering data prove that the inelastic process results from the elastic collision of the incoming electron and one of the proton's quarks. This is an electromagnetic interaction.

QCD.4 In the e-p scattering, the higher energy and the stronger impact of the collision yields a decreasing total cross-section.

QCD.5 In the e-p scattering, the higher energy and the stronger impact of the collision yields a relatively negligible elastic cross-section.

QCD.6 Item QCD.1 means that QCD says that the p-p cross-section is determined by a color-color, like quark-quark (q-q), collision.

QCD.7 The QCD asymptotic freedom says that the effective strong-interaction constant decreases at a shorter quark-quark distance, namely, at higher collision energy (see [10], p. 253). Asymptotic freedom is a crucial element of QCD: "Chromodynamics would have gone out of business if it had not been for the timely discovery of asymptotic freedom" (see [11], p. 301). It should be pointed out that at higher energy, scattering effects are determined by processes that take place inside a smaller spatial volume. Indeed, it is stated above that "to probe *small distances* you need *high energies*" (see [11], p. 6). Hence, *asymptotic freedom means that QCD expects that with the increase of energy, the total p-p cross-section should decrease faster than the total e-p cross-section.* The data of fig. 1 strongly refutes this prediction: the e-p cross section *decreases* with the increase of the scattering energy (see [10], chapter 7) whereas the data of fig. 1 show that at high energy, the p-p cross-section increases with energy.

QCD.8 QCD cannot explain why a heavier blow of an electron-quark collision yields a negligible amount of elastic effects. In contrast, a heavier blow of a q-q collision of the p-p experiment yields a non-negligible amount of elastic events. Furthermore, at higher energies, the number of elastic events of the q-q collision *and* their relative portion increases with energy.

These points demonstrate the QCD inability to explain the rise of the elastic and the total p-p cross-sections with the increase of energy.

The foregoing discussion shows how a specific kind of experiments – high energy scattering of electron and proton on a proton – refute QCD. The rest of this section examines the general features of a physical experiment. The outcome of an experiment in a physical laboratory boils down to a change in time of the state of a specific device. Physical theories use time-dependent differential equations for a description of the time-evolution of the physical system that affects the state of an experimental device. These equations are called the equations of motion of a given system whose properties are described by an appropriate theory. Evidently, fundamental theories like Newtonian mechanics, relativistic mechanics, Maxwell equations of the electromagnetic fields, Einstein equations of the gravitational fields, and the quantum equations of Schroedinger and Dirac take the form of time-dependent differential equations.

The introduction of the variational principle makes an important development in the structure of physical theories. For example, the Noether theorem proves that the differential equations that are derived from the variational principle satisfy certain conservation laws of physical systems (see e.g. [14],pp. 17-22).

It turns out that textbooks of the electroweak theory and the Higgs boson *do not show an explicit form of the differential equations of the* $W^{\pm}$*, the* Z*, and the Higgs boson.* A reasonable explanation for this grave failure stems from the fact that the Lagrangian density of quantum electrodynamics (QED) comprises four terms (see [15], p. 78). In contrast, the electroweak Lagrangian density comprises several dozens of terms, and the corresponding differential equations are expected to take a quite untenable form. The electroweak theories and the Higgs theory are more than 50 years old, and this discrepancy casts serious doubts on their validity.

4 Maxwellian Electrodynamics vs. the Electroweak Theory

Maxwellian electrodynamics is not regarded as a physical principle but it is an extremely accurate theory. For example, it says that the electric field of a motionless charge decreases like $1/r^2$. Consider the expression

$$E = Q/r^{(2+\epsilon)}, \tag{2}$$

where ϵ denote the deviation from this law. The experimental upper bound of $|\epsilon|$ is negligible: $|\epsilon| < 10^{-16}$ (see table 2 in [16]). There is no doubt that a test of an appropriate compatibility of a physical theory with Maxwellian electrodynamics is analogous to its test with a well-established physical principle. This assignment is undertaken here, and the compatibility of the electroweak theory of the electrically charged particles $W^{\pm}$ is examined.

Maxwellian electrodynamics is a theory of two kinds of physical objects: electromagnetic fields and electrically charged particles. The inhomogeneous Maxwell equations are

$$F^{\mu\nu}_{,\nu} = -4\pi j^{\mu}, \tag{3}$$

where $F^{\mu\nu}$ is the tensor of the electromagnetic fields, and j^{μ} is the 4-current of an electrically charged particle (see [6], p. 79).

A contraction of the 4-vectors of (3) yields

$$F^{\mu\nu}_{,\nu,\mu} = -4\pi j^{\mu}_{,\mu} = 0. \tag{4}$$

The null result of (4) stems from the antisymmetry of $F^{\mu\nu}$ with respect to the interchange $\mu \leftrightarrow \nu$ and the symmetric relations of the order of derivative.

Equation (4): $j^{\mu}_{,\mu} = 0$ is a well-known expression that is called the continuity equation (see [6], pp. 76-78). It is an equation that the electrically charged particle must satisfy. The meaning of this outcome is:

Maxwell equations of the electromagnetic fields yield the continuity equation, which imposes a constraint on any theory of an electrically charged particle.

Let us apply this outcome to the electroweak theory. This theory is about 50 years old, and one of its objectives is to explain the $W^{\pm}$ particles. An examination of QFT textbooks that discuss the electroweak theory proves that *no textbook shows the explicit form of the continuity equation of the* $W^{\pm}$ *particles.* The foregoing arguments mean that at present, the electroweak theory should be regarded as an intrinsically wrong theory.

5 Discussion

This work is dedicated to the important task of the coherence-tests of physical theories. It shows that the correspondence principle, the requirement to explain experimental data, and the compatibility with well-established theories (like Maxwellian electrodynamics) can be used for this end. This section provides more arguments that support the foregoing results.

The second section concludes that the theories of the Majorana neutrino and the Proca photon are wrong. The neutrinoless double β decay is a fingerprint of the Majorana neutrino. Many experimental searches for this effect have been carried out, but the present conclusion says that "neutrinoless double beta decay has not yet been found" [17]. Similarly, measurements support Maxwellian electrodynamics of a massless photon and refute the Proca theory of a massive photon. Thus, the present upper bound on the photon's mass is smaller than 10^{-18} eV [12]. It means that, contrary to the Proca assertion, the experimental photon's mass is extremely negligible, and it is smaller than 10^{-23} times the electronic mass! It can also be proved that inherent contradictions exist in the electroweak theory of the Z boson and the theory of the Higgs boson [8]. Hence:

The generalized correspondence principle of section 2 provides a useful test of the correctness of physical theories.

There is no doubt concerning the fundamental role of experiments in the structure of physics. Sometimes experiments precede a theory, and they are used as a clue for its construction. In other cases, experiments serve for a rejection or a support of a given theory. Section 3 discusses one example that refutes QCD.

Here is another example that shows how experiments cast very serious doubt on the validity of the SM. The SM is an assembly of theories, and it says that the $W^{\pm}$ are elementary particles that carry weak interaction. Furthermore, the top quark belongs to another kind of particles, and like all quarks, it participates in strong, electromagnetic, and weak interactions. It means that the SM argues that *these particle have completely different physical properties.* The current data presentation of the Particle Data Group (PDG) is organized according to the SM [12]. Here the $W^{\pm}$ particles belong to the set called "Gauge & Higgs Bosons", while the top quark is described in the set called "Quarks".

Table 1: The decay modes (in %) of the top quark and the W^+ [12]

Channel	top quark	W^+
ν_e + X	11	11
ν_μ + X	11	11
ν_τ + X	11	11
hadrons	67	67

The top quark and the $W^{\pm}$ boson are charge-carrying particles. Let us examine the official report [12] of the weak decay channels of these particles. Table 1 puts side by side the percentage (rounded to two decimal digits) of the neutrino and pure hadronic decay channels of the top quark and the W^+. No one can deny the striking similarity in the data. The SM cannot explain this similarity, because, contrary to the SM concepts, the data favor a theory where the $W^{\pm}$ boson are mesons that comprises a top quark and another antiquark [8]. Here the top quark at its creation state and the bound top quark inside the $W^\pm$ show the same decay features.

Conclusion: *Experimental data of the decay of the top quark and the $W^\pm$ particles cast serious doubts on a fundamental SM feature – its interpretation of particles.*

The impressive success of Maxwellian electrodynamics is used in section 4 as a basis for a refutation of the electroweak theory of the electrically charged $W^\pm$ particles. It is interesting to compare this failure of the electroweak theory of the $W^\pm$ particles with a theory of another charged particle – the Dirac equation of the electron. Thus, although more than 50 years have elapsed since the electroweak formulation, this theory still has no coherent expression for the continuity equation of the $W^\pm$ particles. In contrast, just about one month after the publication of the Dirac theory of the electron [18], Darwin found an expression for the continuity equation of this particle [19]. This dramatic difference between the compatibility of the Dirac theory of the electron with the continuity equation and the corresponding failure of the electroweak theory of the $W^\pm$, emphasizes the problematic status of the electroweak theory. Other inconsistencies of the electroweak theory are discussed in [8]. These inconsistencies support the results of the foregoing application of Maxwellian electrodynamics.

One may conclude that the long duration of this troublesome plight of the 4-current of the electroweak $W^\pm$ means that the electroweak theory is uncorrectable. A recently published book discusses other problematic aspects of this issue (see [8], pp. 184-189).

The topics that are mentioned above are few examples of the variety of coherence tests that can be applied to the SM. Many more cases of this crucial but neglected task are discussed in [8]. This book proves erroneous elements of the SM, that belong to all its sectors: weak interactions, strong interactions, and QED. The reader should recognize that the last point should not come as a surprise. Indeed, Feynman, who was a key person in the QED construction, has called renormalization “a dippy process” (see [20], p. 128). Therefore, If one does not underestimate his opinion then he should realize that the present form of QED must have at least one erroneous element.

6 Concluding Remarks

This work emphasizes the need for compatibility tests of physical theories. Historically, this objective has been applied to the structure of important theories like SR, GR, and quantum mechanics. The compatibility of SR with the non-relativistic Newtonian mechanics and that of GR with the Newtonian theory of gravitation are documented in textbooks. Moreover, the compatibility of quantum mechanics with classical physics is discussed in many textbooks. These cases utilize the correspondence principle. This scientifically needed practice can be extended in these ways: correspondence between other theories can be applied in compatibility-tests of other theories, and other well-established physical principles and theories may also be used as test criteria of any given theory.

This paper points out that the vital task of compatibility-tests of physical theories was an ordinary practice during the first half of the 20th century. Unfortunately, the present mainstream literature ignores it for a long time. As a matter of fact, a comprehensive examination of existing theories is a tremendous assignment, because there are many well-established physical principles and many well-established theories. Each of these issues yields constraints that affect the structure of any given theoretical idea. Therefore, this work provides a few examples that show the effectiveness of this approach and demonstrate inconsistent points of some mainstream physical ideas.

References

[1] P. A. M. Dirac, *The Principles of Quantum Mechanics*, (Oxford University Press, London, 1958).

[2] L. I. Schiff, *Quantum Mechanics* (McGraw-Hill, New York, 1955).

[3] L. D. Landau and E. M. Lifshitz, *Quantum Mechanics* (Pergamon, London, 1959).

[4] A. Messiah, Quantum Mechanics, V. 1 (North Holland, Amsterdam, 1967).

[5] A. Einstein, *Albert Einstein in His Own Words* (Portland House, New York, 2000).

[6] L. D. Landau and E. M. Lifshitz, *The Classical Theory of Fields,* (Elsevier, Amsterdam, 2005).

[7] F. Rohrlich, *Classical charged particle* (World Scientific, New Jersey, 2007).

[8] E. Comay, *Broken Physics*, (E. Comay, Tel Aviv, 2021).

[9] S. Weinberg, *The Quantum Theory of Fields*, Vol. I (Cambridge University Press, Cambridge, 1995).

[10] M. Thomson, *Modern Particle Physics* (Cambridge University Press, Cambridge, 2013).

[11] Griffiths D. Introduction to elementary particles. 2nd edition. (Wiley-VCH, Weinheim. 2008).

[12] P.A. Zyla et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01 (2020) and 2021 update.

[13] G. Antchev20 et al., TOTEM Collaboration, Eur. Phys. J. C **79**, 103 (2019). `https://doi.org/10.1140/epjc/s10052-019-6567-0`

[14] J. D. Bjorken and S. D. Drell, *Relativistic Quantum Fields*, (McGraw-Hill, New York, 1965).

[15] M. E. Peskin and D. V. Schroeder *An Introduction to Quantum Field Theory*, (Addison-Wesley, Reading Mass., 1995).

[16] L. C. Tu and J. Luo, Metrologia **41** S136 (2004) `https://www.researchgate.net/publication/228689980`

[17] The Wikipedia Neutrinoless Double Beta decay Item. (2021). `https://en.wikipedia.org/wiki/Neutrinoless_double_beta_decay`

[18] P. A. M. Dirac, Proc. Roy. Soc. Lond. **A117**, 610 (1928).

[19] C. G. Darwin, Proc. Roy. Soc. Lond. **A118**, 654 (1928).

[20] R. P. Feynman, *QED, The Strange Theory of Light and Matter* (Penguin, London, 1990).