International Journal of Theoretical and Mathematical Physics 2025, 15(1): 1-3
DOI: 10.5923/j.ijtmp.20251501.01

On De Broglie's Wave-Particle Theory

Fleur T. Tehrani

Professor, Department of Electrical and Computer Engineering, California State University Fullerton, Fullerton, California, USA

Abstract The purpose of this paper is to focus on De Broglie's wave-particle duality theorem and examine some questions that can be raised based on that theorem. Those questions pertain to applications of the theorem in non-quantum large particles as well as quantum entities, and the applicability of De Broglie's wavelength formula under different circumstances.

Keywords Wave-Particle Duality Theorem, Intrinsic Energy, Quantum Entities

1. Introduction

In 1923, Louis De Broglie proposed that everything manifested both wave and particle properties [1]. This new hypothesis could explain the nature of light and the manner of propagation of light and quantum entities such as electrons, that had puzzled physicists at that time. The main experiment designed to test this hypothesis was by Davisson and Germer in 1927 [2]. Since that time, many researchers have discussed the uncertainty principle of quantum mechanics that includes wave-particle theory [3]. Many physicists have suggested that the popular wavefunction formulation that is the standard problem-solving method in quantum mechanics is a mathematical tool rather than a physical entity [4,5,6,7,8]. However, the question of the meaning of the mathematics, in relation to the underlying realities of physical laws of quantum mechanics that include the wave-particle theory, has not been clearly answered to this date. More recently, some questions have been raised in regard to applicability of the wave-particle theory to light [9]. This paper examines some questions that can be raised in regard to this theorem, also in view of recent experiments.

2. Raised Questions: Is De Broglie's Formula Based on the Intrinsic Energy Content of Mass and Can It Also Describe Energy Emissions of Quantum Entities?

2.1. De Broglie's Formula is Intertwined with the Equation of Energy Content of Mass

Energy of a wave is given by Planck's equation as:

$$\text{Energy} = h.f \tag{1}$$

Where h is Planck's constant, and f is the wave frequency. The wave frequency is:

$$f = \frac{C}{\lambda} \tag{2}$$

Where C is the speed of light and λ is the wavelength. Substituting f in Planck's equation 1, by C/λ from equation 2 yields:

$$E = \frac{h.C}{\lambda}$$

Where E is energy. Rearranging for λ:

$$\lambda = \frac{h.C}{E} \tag{3}$$

Louis De Broglie proposed that everything manifested both wave and particle properties and came up with the following wave equation:

$$\lambda = \frac{h}{P} \tag{4}$$

In this equation, P is the particle's momentum.

Equation 4 is intertwined with the equation for the intrinsic energy of mass [7,8] and can be derived from that equation as shown below:

Energy content of a particle with mass m_0 is given by:

$$\text{Energy} = m_0 C^2 \tag{5}$$

Where m_0 is the particle's mass.

Equation 5 can be expanded as:

$$\text{Energy} = m_0 C^2 = m_0.C.C = P.C \tag{6}$$

Where $P = m_0.C$

If it is assumed that at the speed of light, all the particle's mass is converted to energy, the frequency of the wave of energy will be given by equation 2 as:

$$f = \frac{C}{\lambda}$$

Substituting C in equation 6 by f.λ from equation 2 yields:

$$\text{Energy} = P.C = P.\lambda.f \tag{7}$$

---

* Corresponding author:
ftehrani@fullerton.edu (Fleur T. Tehrani)
Received: Jan. 16, 2025; Accepted: Feb. 5, 2025; Published: Feb. 8, 2025
Published online at http://journal.sapub.org/ijtmp

Energy of a wave is given by Planck's equation 1 as:

$$\text{Energy} = h.f$$

Equating equations 1 and 7 yields:

$$\text{Energy} = P.\lambda.f = h.f \quad (8)$$

Dividing all sides of this equation by f and rearranging it for λ yields:

$$\lambda = \frac{h}{P}$$

which is De Broglie's equation 4.

Based on this equation, the following questions can be raised.

2.2. Are Non-Quantum Particles Associated with Waves in Motion as Proposed by the Wave-Particle Theory?

The validity of equation 5 which is considered as a law, has been confirmed by many experiments. Equation 5 indicates that mass is convertible to energy, which further indicates that mass and energy may be considered as fundamentally the same despite being considered as different physical entities. This equation shows the intrinsic energy content of a particle as given by m_0C^2.

If one accepts that non-quantum particles are associated with energy waves in motion at a wavelength λ as given by De Broglie's formula (equation 4), where does that energy field of the particle come from? The proposed energy waves of large non-quantum particles have not been confirmed experimentally. There is no experimental report showing the proposed energy waves of even small, microscopic, non-quantum particles. It has been explained that since for particles that are not at the atomic and sub-atomic levels, λ is very small, it cannot be detected and measured experimentally. However, this does not explain/prove that non-quantum particles are associated with energy waves in motion.

2.3. Are Quantum Particles Associated with Energy Waves with Wavelengths Given by De Broglie's Formula, Equation 4?

Davisson and Germer reported that the wavelength of electron beams energized by thermionic emission, was measured as predicted by De Broglie's formula (equation 4). In the reported experiments, electrons' masses were not converted to energy. The experimental results were used to prove the wave nature of electrons, and that matter manifests both particle and wave characteristics [2].

According to De Broglie's theory, electrons that are bound in the atomic structure are associated with a wave where the wavelength is given by equation 4. In the experiments reported by Davisson and Germer [2], the electron beams were made of free electrons energized by thermionic emission and further accelerated by an external electric field. The propagation pattern of those beams was found to be a wave pattern. The wavelength was calculated in accordance with De Broglie's formula, equation 4, where momentum, P, was found from the kinetic energy of electrons provided by the external electric field. One could argue that the observed calculated wavelength in those experiments was not necessarily associated with the wavelength of electrons bound in an atomic structure. The question arises that if electrons are energized in other types of experiments, will the wavelengths of energies given off by those electrons be in accordance with equation 4?

Electrons have been known to give off energy under certain circumstances. When energized electrons go back to their initial quantized levels of energy, they give off the difference in the energy levels. In that process, the frequency of the electron's given off energy wave is directly proportional to the energy difference between the two energy levels and is given by:

$$f = \frac{E2 - E1}{h} \quad (9)$$

where E2 and E1 are the higher and lower energy levels respectively. The question arises if the wavelength of this type of radiation can be calculated in accordance with De Broglie's formula.

Further, free electrons energized in a magnetic field can give off energy. In a set of experiments designed to measure the neutrino's mass, single electrons were energized in a cyclotron and the energies given off by electrons were measured [10,11]. The frequency of those energy waves was reported as proportional to the magnetic field intensity inside the cyclotron. There was no indication in the reports of whether the wavelengths were measured to be in accordance with De Broglie's formula.

3. Summary

According to some reported experiments [2], energy as well as particles at subatomic levels are observed to propagate in waves. This is plausible; sound propagates through the substance as energy waves and those waves may contain small particles [12]. De Broglie's formula (equation 4) can be derived from equations 1 and 5 and is intertwined with the intrinsic energy content of mass. The following questions can be raised in regard to applicability of De Broglie's formula, equation 4, under different circumstances:

1. If a non-quantum particle is associated with an energy wave, a phenomenon that has not been confirmed experimentally, where does that field of energy come from and how this phenomenon can be verified experimentally.
2. Davisson and Germer experiment [2] was focused on beams of free electrons energized by thermionic emission and accelerated by an external electric field. Davisson and Germer did not calculate the wavelength of any electron wave for any electron bound in an atomic structure and they used the external kinetic energy provided to electrons to calculate momentum, P, in equation 4. At the quantum levels, mass and energy are quantized and quantum entities are assumed to give off energy to keep their energies at allowed levels.

In some experiments on quantum entities such as experiments on excited electrons giving off energy in moving from one level of energy to a lower level, or when free electrons are energized in cyclotrons, the applicability of equation 4 has not been reported and may need to be addressed.

The above questions may deserve to be addressed to determine the scope of applicability of equation 4 and the wave-particle duality theorem under different circumstances.

Data Availability

Data generated or analyzed during this study are available from the corresponding author upon reasonable request.

Author Information

Author ORCID:

Fleur Tehrani: https://orcid.org/0000-0001-8621-7697

Author contributions

Writing, Review and Editing: F.T. Tehrani

Competing interests

The author declares there are no competing interests

REFERENCES

[1] L. V. De Broglie. On the Theory of Quanta; A Translation of: Recherches sur la théorie des Quanta (*Annalen der Physik*. 10e Série, t. III (Janvier-Février 1925); Kracklauer, A.F., Ed.; AFK: Paris, France, (2004). https://fondationlouisdebroglie.org/LDB-oeuvres/De_Broglie_Kracklauer.pdf.

[2] C. Davisson and L. H. Germer. *The Physical Review*, 30, no. 6,705-741 (1927). https://journals.aps.org/pr/abstract/10.1103/PhysRev.30.705.

[3] J. G. Cramer. The Transactional Interpretation of Quantum Mechanics, *Reviews of Modern Physics*, 58, 647-687 (1986). DOI:10.1103/RevModPhys.58.647.

[4] E. T. Jaynes. Scattering of Light by Free Electrons as a Test of Quantum Theory. In Proceedings of the Workshop on “The Electron,” St. Francis Xavier University, Antigonish, NS, Canada (1990). https://bayes.wustl.edu/etj/articles/scattering.by.free.pdf.

[5] D. F. Styer, M. S. Balkin, K. M. Becker, M. R. Burns, C. E. Dudley, S. T. Forth, J. S. Gaumer, M. A. Kramer, D. C. Oertel, L. H. Park, M. T. Rinkoski, C. T. Smith, and T. D. Wotherspoon. Nine Formulations of Quantum Mechanics, *American Journal of Physics*, 70, 288-297 (2002). DOI:10.1119/1.1445404.

[6] M. Muhibbullah and Y. Ikuma. Refutation of the short report ‘On the impossibility of “Photoelectron ejection by EM wave”’. *Optik*, 202, 163734 (2020). https://doi.org/10.1016/j.ijleo.2019.163734.

[7] F. T. Tehrani. On Lorentz Transformations and the Theory of Relativity. *Journal of Modern Physics*, 13, 1341-1347 (2022). https://doi.org/10.4236/jmp.2022.1311083.

[8] F. T. Tehrani. Lorentz Transformations and the Theory of Relativity: A Fundamental Concept, *Fundamental Research and Application of Physical Science*, vol. 4, chapter 1, First Edition (2023). https://doi.org/10.9734/bpi/fraps/v4/4379C.

[9] M. Muhibbullah and Y. Ikuma. Transition of Orbital Electrons by Electromagnetic Waves. *Optics*, 4, 258–271 (2023). https://www.mdpi.com/2673-3269/4/2/18.

[10] P. Huber. Viewpoint, Cyclotron Radiation from One Electron, *Physics*, 8, 36, (2015). https://physics.aps.org/articles/v8/36.

[11] B. Monreal. Single-Electron Cyclotron Radiation, *Physics Today*, 69 (1), 70–71 (2016). https://doi.org/10.1063/PT.3.3060.

[12] A. Esposito, R. Krichevsky, and A. Nicolis. Gravitational Mass Carried by Sound Waves, Physical Review Letters, 122, 084501 (2019). https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.122.084501.