Matter Waves

Exactly what is an electron? Albert Einstein was puzzled about matter: "You know, it would be sufficient to understand the electron". The consensus on the *dual nature* of electrons is much like that of two blind men who found an elephant. One felt the elephant's tail and declared he was touching a rope. The second man put his arms around one leg of the elephant and announced he had encountered a tree. Each man thought he had made an informed and valid assessment; in future discussions they considered each other's evidence and concluded that the "elephant" had a dual nature.

Understanding Matter. The highest priority of physics should be an accurate description of matter. An understanding of matter allows prediction of its motions, its physical and chemical properties, and its interactions with other objects and light. However, twenty-five centuries of speculation, deduction, and experimentation have produced models and theories that are unacceptable to philosophers and even some physicists who still believe that a self-consistent theory of matter should be the goal of physics.

> "I think it is safe to say that no one understands quantum mechanics. Do not keep saying to yourself, if you can possibly avoid it, 'but how could it be like that?' because you will go 'down the drain' into the blind alley from which nobody has yet escaped."
>
> —*Richard Feynman, Nobel laureate*

Splitting of the atom in the twentieth century demonstrated by numerous experiments that electrons and protons are the material constituents of the atom—the very building blocks of matter in all the variety of form observed in everyday experience.

Particle-Wave Duality. One of the strangest twists in the history of physical theory originated in 1924 when Louis de Broglie proposed "the existence, in a wave, of points where energy is concentrated, of very small corpuscles whose motion is…intimately connected with the displacement of [a] wave…." [Quoted by A. P. French, *Principles of Modern Physics,* p. 175, John Wiley & Sons, Inc. (1958)] In a short time, de Broglie's idea came to mean that a given electron could exhibit properties that are associated with a particle, *or* it could exhibit properties that are associated with a wave.

> "While electrons were useful to understand many other things, we never really understood the electron itself."
>
> —*Louis de Broglie, Nobel Laureate*

"De Broglie's treatment…stood for three years before being tested, and then in the years 1927-1928 the diffraction of electrons was experimentally demonstrated by Davisson and Germer (reflections from a crystal face) and by G. P. Thomson (transmission through thin foils)." [French, p. 179] Later, a beam of electrons aimed at double slits produced bright lines at spaced intervals on a screen behind the slits. Apparently, the electron, thought to be a particle, also exhibited the properties of a wave, and the prevalent philosophy of *naturalism* dictated that the electron must *be* what was *observed;* in other words, the essence of an electron was supposed to be the same as the two fundamental properties it exhibited.

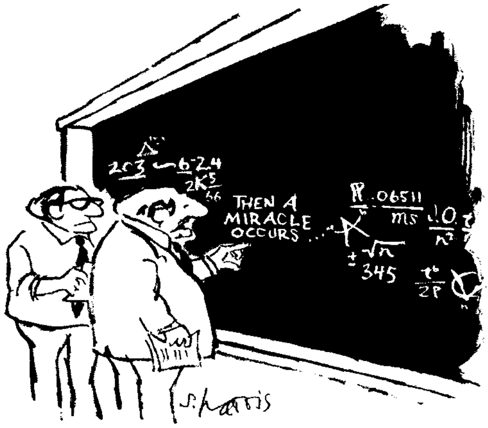
Ontology of the Electron. For some, ascribing a wave nature to an electron created a dilemma, since the discovery by J. J. Thomson in 1897 of the electron demonstrated just as convincingly that the electron is a particle, *i.e.* an object with size, shape, and boundaries—properties not at all like the properties of a wave. "To be more explicit, if wave and particle descriptions appear to be mutually exclusive, at least one of them would have to be presumed false in classical physics. Things are quite different in quantum physics: Both descriptions are equally valid, in Bohr's view, provided that one does not insist that they be so at the same time. There is no fundamental problem as long as one does not ask whether an electron *is* a particle or a wave, but simply whether it *behaves* like one or the other in a given situation. In quantum mechanics, the former question is meaningless, according to Bohr, while the latter is easily answered, provided that the experimental conditions [are] clearly stipulated. Thus, in Bohr's conception, complementarity does not resolve the incompatibility between the wavelike and particle-like behaviors of an electron. It simply acknowledges that both descriptions are necessary to encompass all properties of that entity. The logic of this proposition is based on the argument that because of the uncertainty relations—themselves a consequence of the quantum of action—the two properties can never be found in conflict as they never exist at the same time.

As Louis de Broglie had put it: 'People always expect a battle between the wave and the particle: it never happens because never more than one of the combatants shows up.'" [B. Pullman, *The Atom in the History of Human Thought,* p. 299-300, Oxford University Press (1998)]

Significance of an Observation. Agreeing with Hippocrates (*c.* 460-377 BC) who stated that "every natural event has a natural cause," most people believe they have never witnessed a truly random event; such matters are outside the realm of common experience. How then, did modern physics come to assert the *law of chance* and make random events the central principle of its most fundamental theories? The first major step occurred when Einstein introduced the *Principle of Constancy* of the speed of light in his famous 1905 paper on Special Relativity. Einstein asserted that light always moves with a constant velocity. Since the same paper first introduced the *Principle of Relativity* (which is a method of measuring velocity that Einstein himself acknowledged was "quite irreconcilable" with Constancy) we should ask, how is this velocity of light measured—from what platform? To Einstein, this doesn't matter, because all *observers*, moving or stationary, should measure the same velocity for light. In some unspecified way, light is supposed to have a velocity attribute of a constant *c, wherever measured.*

From this illogical notion of the interaction between *light* and an observer came the quantum theory of an interaction between *matter* and an observer. "Quantum theory is peculiar in that it describes a *measured atom* in a very different manner than an *unmeasured atom*. The measured atom always has definite values for its attributes (such as position and momentum), but the unmeasured atom never does. Every atom in the world that's not actually being measured possesses (in the mathematical description at least) not one but all possible attribute values, somewhat like a broken TV set that displays all its channels at the same time…. In brief, the Copenhagen Interpretation holds that in a certain sense the unmeasured atom is not real: its attributes are created or realized in the act of measurement." [Nick Herbert, Quantum Reality, Anchor Books—Doubleday, pp. Xii-xiii (1985).

Quantum Reality. So then, just how does Quantum Theory describe an electron or any material object? An electron is first, and foremost, a structureless entity described statistically as a *wave* that corresponds to the orbit of an electron moving randomly about an atomic nucleus. When measured in certain ways, the wave demonstrates its frequency and wavelength—just as any beam of light—by diffraction and interference patterns. Believers in particle-wave duality say that the interference patterns generated from a beam of light passing through two slits give evidence of the electron's wave nature. If the electron really is a wave, and not simply a small object that can generate waves, then the electron is spread out over space with dimensions that account for its wavelength.



"I think you should be more explicit here in step two."

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However, Niels Bohr and other experts on quantum theory also knew about the experimental evidence for quantum features of electrons—evidence from spectra, Planck's treatment of blackbody radiation, and Millikan's oil drop experiment. The electron must be a *particle* to allow physicists to predict many of its fundamental properties, such as rest mass, quantum of charge, magnetic moment, and spin. The founders of quantum mechanics had little interest in the particulate nature of the electron and chose to treat the electron as point-like. Dirac showed the way in 1938: "We shall retain Maxwell's theory to describe the field right up to the point-singularity which represents our electron and shall try to get over the difficulties associated with the infinite energy by a process of direct omission or subtraction of unwanted terms, somewhat similar to what has been used in the theory of the positron. Our aim will not be so much to get a model of the electron as to get a simple scheme of equations which can be used to calculate all the results which can be obtained from experiment…. Provided these conditions are satisfied, it should not be considered an objection to the theory that it is not based on a model conforming to current physical ideas." [P. A. M. Dirac, "Classical Theory of Radiating Electrons", Proc. Royal Soc. of London, vol. CLXVII, p. 149 (1938)]

While some consider the wave and particle descriptions of an electron to be mutually exclusive, Niels Bohr took the view that "both descriptions are equally valid, …provided that one does not insist that they be so at the same time." [Bernard Pullman, The Atom in the History of Human Thought, Oxford Univ. Press (1998)]. This requires a new concept—the famous "wave collapse"—to declare the transition of an electron from its particle expression to its wave expression. The particulars of a "wave collapse" are vague, disputed, and indefensible—even by specialists of the theory. Some handle this embarrassment with humor, as shown by the cartoon published in the May, 1997, issue of PHYSICS TODAY.

Philosophy. *Materialism* is the name of this philosophy that ascribes power to matter, whether we speak of the atom or the electrons and protons that make up the atom. The philosophy of materialism has strong implications for philosophy as well as science, and the same arguments used by the ancient Atomists have been adopted by quantum theorists: "Thus, the inherent power of the atom to move by its own weight plus its equally inherent power to swerve from its normal path, plus its power to cling together with other atoms both like and unlike itself, plus the law of chance, can and do account, of and by themselves, without the intervention of any outside force or guiding intelligence, for every form of being that can be observed by one or another of our senses." [F. Copley, *Lucretius, The Nature of Things,* p. xii, Norton (1977)]

While ancient Greek thinkers searched for things essential and universal, twentieth century physicists redefine the meaning of "essential" to include "atoms" that have *inherent power to change form, properties, and even their essential nature.* Although the root-word meaning of "science" is knowledge, one can be forgiven for thinking that the original purpose for science has been abandoned. What began as a search for order and essentials in nature turned from the *law of cause and effect* to the *law of chance*, best known today as the Heisenberg Uncertainty Principle. In his epic study "A History of the Sciences", Stephen Mason described the early Atomists' philosophy when he wrote: "They used the atomic philosophy mainly to combat religion, not to extend man's understanding and control of nature." [S. F. Mason, *A History of the Sciences,* p. 62, Collier Books, Macmillan (1962)]

Determinism. Louis De Broglie, who first proposed matter waves, apparently did not like the new powers that came to be ascribed to the electron: (1) the power to alternate between mutually exclusive attributes; or (2) a later development, the power to emit photons at random times. He "refused to accept this intrinsic breakdown of causality in the subatomic world" and stated that "it seems to us entirely plausible that physics will someday return to the fold of determinism…." [Pullman, p. 294]

Logic. Nevertheless, the errors in science concerning particle-wave duality do not end with the problems of logic listed above. Evert Jan Post writes that "The wave-particle duality compares things that are fundamentally incomparable. Orthonormal decompositions indicate that the mathematical artifact, called wave, always retains an intrinsic plurality connotation, which is not compatible with a singular item. This is at best a many particle-wave duality!" [E. J. Post, "The Unreasonable Persistence of Questionable Physical Doctrine", Galilean Electrodynamics, vol. 10, number 2 (March/April 1999).]

Wave Packets? Quantum theory doesn't usually try to *explain* its models, but simply assumes inherent attributes and powers; quantum theorists often claim that no better theory is available. In this case, however, an attempt was made to explain how properties of an object are combined with the properties of a wave using the notion of a *wave packet.* However, a wave packet having the right wavelengths and frequencies cannot be localized, just as stated by Post and shown by Fourier analysis.

Essential Nature of Electrons. While few would doubt the particle nature of electrons, many physicists accept the double-slit experiment performed with a beam of electrons, instead of monochromatic light, as incontrovertible evidence for the wave nature of electrons. Forgetting the lesson of the blind men who encountered an elephant, these scientists insist that the wave nature is the most fundamental thing about the electron—in short, its essence. Actually, there are several possible ways to describe the nature of an electron:

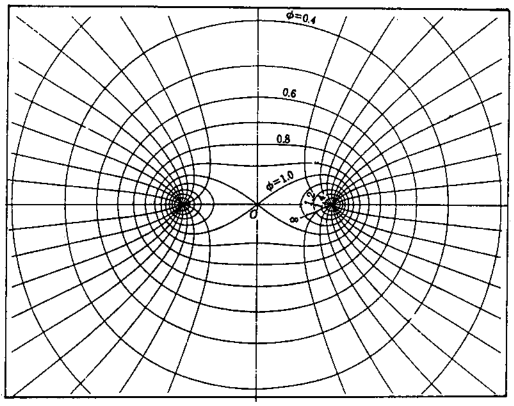
1. An electron has a dual nature, with corpuscular or wave nature, but takes on one nature at a time, according to its own prerogative and inherent powers (the position of Niels Bohr).

2. An electron is co-natured, being both a corpuscle and wave at the same time (the position of Bert Schreiber.)

3. An electron has a single nature, consisting of electrostatic charge (and two corresponding electromagnetic fields) arranged in a geometry that is able to produce the properties of a particle and/or a wave in experiments (the position of Parson, Iida, Bostick, and Common Sense Science).

Charged Ring Model. The ring electron is composed purely of electrostatic charge, the essential "stuff" that provides its attributes. These attributes—size, shape, electric and magnetic fields, standing waves, stability, *etc.*—are not assumed, intrinsic characteristics, but properties derived from the ring's charge and geometry in accordance with established laws of electromagnetism.

With one consistent, unchanging nature, the spinning charged ring electron simultaneously presents observers with the particle properties of a *localized* object and the wave properties of an *extended* object. The corpuscular, or particle-like, properties of the ring electron are its size, shape, and boundaries. The wave-like properties of the ring electron are its standing wave, extended forces (*i.e.,* action-at-a-distance), and spectral lines with wave-lengths (both integer and sub-integer multiples of its circumference).



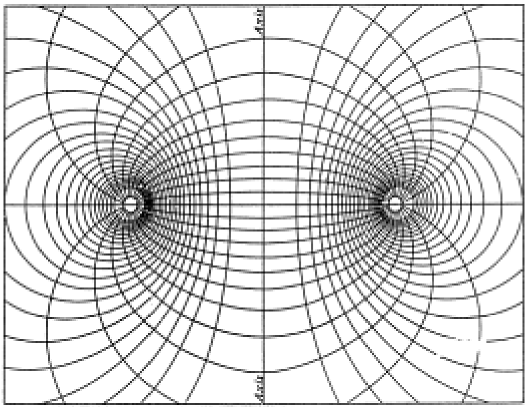
Electrostatic Field of a Ring Electron

The ring and the field illustrate both the localized particle *and* one of its extended fields.

All these properties of a ring electron are observable in appropriate experiments. Any material object, electron, proton, neutron, *etc.,* or an object composed of these particles, *always has electrostatic charge present.* The electric and magnetic fields that result from charges in material are additive (being superimposed) even while the total charge on an object may be neutral due to an equal number of positive and negative charges distributed throughout the object. In contrast, light is not composed of charge or charged particles, but only fields. Thus, the inertial mass of material objects can be derived for material objects (see Common Sense Science papers **CO1, CO2, SP2,** & **LN1**), but light is composed only of field energy and has no inertial mass.

Double-Slit Experiment. The accompanying figures show the shape and strength of two fields that surround a free electron. Under normal conditions for a beam of electrons streaming toward two slits, the electrons interact, exchange energy through the fields that surround each electron, and are in constant *oscillation*. Both the charge of the electron and its two surrounding fields are in oscillation.

The oscillating fields from a given electron spread out in space, arriving at both slits. The electron particle itself may or, more likely, will *not* pass through either slit. But the oscillating electric and magnetic fields proceedings from each electron are coherent (phase related) and do pass through the slits. Depending upon their wavelengths, these oscillating waves will produce constructive and destructive wave fronts on a screen placed behind the slits. This part of the experiment is the same as the production of interferometry lines on a screen using a source of monochromatic light instead of a beam of electrons.



Electromagnetic Field of Ring Electron

Conclusion. The *quantum mechanics model of the electron* ascribes fundamental properties and a dual-nature to the electron, leading to many accurate predictions of its measured properties. The incorrect predictions made by quantum theory for the electron's fundamental properties of spin, mass, and magnetic moment are ignored—these properties being assigned experimental values to replace the values a point would have under the laws of electromagnetism. In the quantum model, the statistical description of electron motions is based on *random* events instead of *cause and effect* relationships.

The *ring model of the electron* predicts both particle and wave properties of the electron that are observed in experiments. This classical, dynamic model has physical properties that adjust to the ambient electromagnetic environment because of *causal* relationships. The model closely conforms to the actual physical reality of the electron. Inertial mass and forces acting across space on other electrons are derived from the electron's essential material—*charge.* The ring model is self-consistent, consistent with experimental data suggesting particle *and* wave properties, does not violate the *law of cause and effect,* and rejects the metaphysical interpretations of an entity with two natures.