Models of the Electron

Before the end of the 19th century, J. J. Thomson was able to demonstrate the existence of a small particle that is named the electron. It has a small and definite amount of electric charge and a small and definite amount of inertial mass. Leading scientists of the day promptly developed models for the electron and performed experiments to validate their ideas. The classical physicists believed that the electrical particle they discovered was a fundamental building block of matter—what we would call an *elementary particle;* and that electrons were contained in ordinary objects that we observe every day.

> **Quantum Electron**
>
> Physically, an elementary particle is regarded as a stable, point-like, structureless entity (structureless except for having mass, spin and other possible quantum numbers) which in its free state, moves on a world line with momentum *k*.
>
> *—John Fang, California State Polytechnic University at Pomona in* PHYSICS TODAY, *p. 90, July 1997.*

Some classical physicists also believed that electricity and magnetism could account for the physical properties of matter such as inertia, the color of objects, the gravitational force between masses and the crystalline structure of certain molecules. In other words, a concept developed that matter has an electromagnetic nature that explains what is observed about matter.

For over 100 years, physicists have realized that an understanding of electrons is important for the development of science. A majority of physicists adopted *relativistic mathematics* and a *law of chance* as guiding principles to predict natural phenomena. A small minority, mostly ignored, continued to look for order in the universe with models and theories based on *causality* and a conviction that a description of matter in physical terms could be discovered and validated.

Historical Models. Several models were soon proposed for the electron discovered by J. J. Thomson in 1897. Electric charge compressed to the shape of a **sphere** or a **ring** were proposed and evaluated on the basis of classical electrodynamics. In the years that followed, a new quantum theory evolved that integrated the **point electron** and the **quantum electron** into the Standard Model of Elementary Particles.

> **Electron in an Atom**
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> [A]nother convenient and useful representation, often preferred by chemists, …depicts an electron as spread out in a kind of charge cloud, the density of which corresponds to the local probability of presence of that electron.
>
> —*Bernard Pullman*, The Atom in the History of Human Thought*, page 280, Oxford University Press (1998).*

The earliest model of the electron consisted of charge distributed over the surface of a small sphere. From the known mass, which was assumed to be of electromagnetic origin, a "classical electron radius" of 2.82×10^{-15} meters was calculated. Max Abraham advocated a perfectly *rigid sphere,* while H. A. Lorentz proposed a *deformable sphere* that contracted in accordance with its velocity. Neither was aware of the electron's spin (angular momentum) or magnetic moment, and their non-rotating spheres therefore made no attempt to account for these features.

For four reasons, a *spherical* electron is untenable:

1. Strong Coulomb forces from charge concentrated in a small area would make the electron explode.
2. No force has been found to balance Coulomb forces at the surface of a spherical electron.
3. To produce the observed magnetic moment of the electron, a rotating sphere would need a peripheral velocity far in excess of the speed of light.

4. The mass-energy equivalence of electric charge on a sphere provides only 75 percent of the electron's effective mass: *i.e.,* $E_o = (3/4)\, m_o c^2$.

Another classical model was proposed for the electron by Parson[1] in 1915. His model consisted of charge distributed over the surface of a **spinning ring**. While the sphere has only one degree of freedom, radius R, Parson's spinning ring has three degrees of freedom, radius R, half-thickness r, and rotation rate ω, providing more opportunity for characteristics of the ring model to conform to the electron's measured parameters. As a proposed basic constituent of ordinary matter, the spinning ring model electron gave promise of explaining many of the properties measured in various materials. At a meeting of the Physical Society of London held October 25, 1918, Dr. H. S. Allen, *M.A., D.Sc., University of Edinburgh* presented *"The Case for a Ring Electron*."[2] At this meeting, "Dr. H. S. Allen discussed the arguments in [favor] of an electron in the form of a current circuit capable of producing magnetic effects. Then the electron, in addition to exerting electrostatic forces, behaves like a small magnet. The assumption of the ring electron removes many outstanding difficulties...."

Dr. Allen's presentation described the advantages of the ring electron. Although Parson's ring electron had features to be taken seriously, and explained more phenomena than any other model, its advocates relied on estimates and even erred in listing some of its properties. Most notable was the value given for its spin, a value equal to $h/2\pi$ where h is Planck's constant, instead of the empirically correct value of one-half this amount. Perhaps for this reason, or for other reasons not stated, most scientists today adopt the Standard Model, which considers the electron to be a quantum object with particle-wave duality.

As a *particle*, the **point model** of Quantum Theory (QT) eliminates the spatial extent of the previous models "by a process of direct omission or subtraction of unwanted terms." As stated by P. A. M. Dirac, the aim is "not 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 that can be obtained from experiment." The point model is actually a *mathematical model* and is "not based on a model conforming to current physical ideas."[3]

Like the spherical models, the point model is physically unstable. Worse, it requires the density of the particle's rest mass energy to be *infinite*. According to the laws of electrodynamics, a point particle with the known charge measured for an electron would have to have zero spin and zero magnetic moment and would immediately fly apart due to the Coulomb repulsive force. Rather than discard the point model for its erroneous predictions, the model is *endowed* with the empirically correct fundamental properties by *proclamation*, giving credence to a cynical view wherein modern science has accomplish more by consensus and fiat than by logic.

Under the vivid imagination of modern "scientific" leaders, the point model persists in current scientific literature—being incorporated into quantum electron theory—and has become the dominating electron theory of our day.

The modern concept of a **quantum electron** exhibiting wave-particle duality has been set forth by Bohr, Dirac, Heisenberg, Schrödinger, deBroglie, Born, Feynman, and others. According to this model, "a non-relativistic free particle, of energy $E = mv^2/2$ and angular momentum $p = mvR$, is associated with a wave of frequency $\nu = E/h$ and wavelength $\lambda = h/p$."[4] This wave, or a set of waves that form a wave packet, is mathematically described by the Schrödinger wave function expressed by $\psi(x,t)$. A physical interpretation of the Schrödinger wave function was formulated by Max Born and "states that the quantity $\psi{*}\psi' = |\psi|^2$ is to be interpreted as a *probability density* for a particle in the state ψ." This description of the quantum electron is essentially a mathematical construction with only a tenuous link to a physical interpretation or a physical structure. The question of electron *stability* is simply disregarded as not relevant, since the essence of the model is mathematical and not physical.

Many scientists have concluded that none of the historical models provides a satisfactory explanation of the observed features of the electron. The McGraw-Hill Encyclopedia of Science and Technology states that

> "a good theory of electron structure still is lacking…. There is still no generally accepted explanation for why electrons do not explode under the tremendous Coulomb repulsion forces in an object of small size. Estimates of the amount of energy required to 'assemble' an electron are very large indeed. Electron structure is an unsolved mystery…."[5]

Properties of Electrons. Various observations of electrons have revealed their major properties. A successful model must be in agreement with these properties.

Charge. The electron carries (actually, consists of) one unit of charge *e*, considered by convention to be negative in order to relate to the positive charge of the proton.

Stability of the Free Electron. As a free particle, isolated from other particles, the electron is stable. As far as is known, this stability is for an indefinite period. Since like charges repel, some binding force is required to hold the electron together. Classical

Theory must explain electron stability on the basis of the laws of electricity and magnetism; QT is content to specify that the electron is *inherently stable*.

Stability When Bound in an Atom. As a particle bound in an atom or molecule, the electron is also stable. This invalidates the Bohr model of the atom because an orbiting electron has no orbital stability mechanism and would suffer "radiation death" from the continuous centripetal accelerations of the charged particle.

Mass-Energy. Each electron has a mass and a mass-equivalent energy related by Einstein's equation, $E = mc^2$. By applying electromagnetic theory to the ring electron, the energy is described as residing in the electrostatic and magnetostatic fields that give shape to the particle. QT regards the mass as an *inherent property* of the electron.

Magnetic Moment. Each electron has a fixed magnetic moment equal to the product of its area and current. For a ring electron, the magnetic moment may be calculated as $\mu = \pi R^2 I$. QT regards the magnetic moment as an *inherent property* of the electron.

Extent (size). There is much confusion about the electron's size. Although Dirac considered the electron to be a point of zero extent, his purpose was for mathematical convenience and not intended as a physical description. Some quantum theorists write about Dirac's point electron as though this is the actual size,[6] and others describe a point-like model. According to classical physics and the laws of magnetism, *the electron must have some physical extent in order to have a magnetic moment.* As early as 1919, Arthur Compton performed scattering experiments to determine the size of the ring electron.[7] Hofstadter measured the charge distribution of neutrons and protons and received a Nobel prize in physics for his work (physics, 1961), providing strong evidence that these particles have a non-zero size.[8]

Spin. The spin (angular momentum) of an object is equal to mvR where m is the mass rotating with velocity v at a radius R about the axis of rotation. Experiments have established that the spin of an electron is non-zero and stays constant at a value equal to $h/4\pi$, demonstrating a finite size for the electron (*i.e.,* $R > 0$). Quantum theorists often specify a point charge of zero size and deal with this contradiction by claiming that the laws of classical physics do not apply to elementary particles and that the spin of an elementary particle is an *inherent property.*

Gyromagnetic Ratio. This ratio of spin to magnetic moment has been carefully measured and found to be slightly anomalous, *i.e.,* the $g/2$ factor is slightly larger than one. Until recently, there has been no classical explanation for the anomaly. QT claims the anomaly is the result of radiative transitions: emission of photons when an orbital electron spontaneously changes energy states—wherein two violations of logic occur: (1) stability of the atom *postulated against the known loss of energy* (called "radiation death") by an orbiting electron and (2) *assumption of spontaneous events* governed by the law of chance (Heisenberg Uncertainty Principle) which is never observed in ordinary experience and now *shown to by false by empirical evidence.*[9]

Inertial Mass. Since the electron detection experiment by J. J. Thomson, physicists have known that the electron has an inertial mass that tends to resist attempts to change its velocity. By applying classical electrodynamics to the ring electron, we recently found a *cause* for the inertial force in the electromagnetic fields surrounding an accelerated electron.[10] QT regards inertial mass as a fundamental, *inherent property.*

Particle Characteristic. The electron is generally classified as an elementary particle (not composed of other particles). Certain phenomena such as the photoelectric effect, fluorescence, and the Miliken oil drop experiment show that the electron has a small and quantized amount of mass and charge, indicating a particle with a *boundary* and a *location*. QT denies the boundary (an *observed* electron is said to be a point! how can anyone see a point?) and specific location, claiming instead that the product of an electron's location and momentum is at least as varied over time as the magnitude of Planck's constant in the Heisenberg Uncertainty Principle).

Wavelike Characteristic. Diffraction and interference experiments show that sometimes an electron demonstrates the properties of waves. These observations seem to contradict the particle characteristic. If an electron is a point particle without fields, ***it's range of influence on another particle is limited;*** as a wave**,** an electron can exert influence over a long range, reaching beyond its boundary ***to accomplish 'actions at a distance***.'

These incongruous properties lead to QT's claim that the electron has a **dual nature:** Which nature is exhibited depends upon the experiment performed. Neils Bohr argued that the electron could be either a particle or a wave, provided it was not both at the same time[11, p. 299]. Prominent quantum theorists accept the notion of dual essence of the electron and state that human contemplation or measurement of a quantum wave causes the wave to "collapse." "According to… John von Neumann… and Eugene Wigner… no apparatus or measurement scheme, no matter how sophisticated and complicated, could by itself ever cause the "collapse" of the wave function. It is only when the result of the measurement is registered and recorded in the mind of a human being—an animal, even a highly developed one, will not do—that the wave function 'collapses' into an observable reality"[11, p. 280]. (The character of this claim is metaphysical rather than scientific.)

Other QT experts claim that "Nature" causes the wave collapse, ascribing the power of changing its essential nature to the electron itself. For this reason, QT is classified as a *material* or *pantheistic* philosophy. Some even deify nature with a capital "N" or a name such as the Greek goddess of the earth, "Gaea."

Until recently, classical theoretical approaches offered no explanation for the wavelike property (although writings on Parson's ring electron hinted at a classical explanation). We now know that the ring model of the electron as a loop of circulating current will resonate with standing waves that are constrained to a multiple number of wavelengths (with peaks and nodes of electromagnetic field intensity) formed around the circumference of the ring. Also, the classical electrodynamic behavior of the ring electron's fields provide a causal explanation for the wavelike phenomena observed (*e.g.,* electrons in a double slit experiment).

Technological Benefits. Over one hundred years have passed since the electron was discovered. The technology of Electric Field Theory has delivered electric light bulbs, electric motors, radar, electronics, communications, and computers. Many laws of electricity and magnetism have been researched, documented and taught throughout the world.

Billions of dollars are invested in high-tech accelerators and colliders for quantum theorists to learn more about the electron. And yet, despite tremendous efforts over the last nine decades, modern physics still has not developed an accepted model to explain the stability or structure of the electron. The models and theories offered violate logic and force defenders of QT to abandon the Scientific Method and adopt a philosophy that attempts to predict natural phenomena without explanations—and gives preference to mathematics models over physical models of physical reality.

Quantum theorists continue to be embarrassed by the lack of practical applications that provide human benefits from their theories. If compelled, three applications are cited: the laser, the Scanning Electron Microscope (SEM) and transistors.[12] But functions of these devices depend upon electromagnetic fields, not quantum tunneling. In its article on the laser, an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation, the *McGraw-Hill Encyclopedia of Science and Technology* inserts the word "electromagnetic" before "Radiation" and explains that "lasing" is stimulated by coherent (phase related) electromagnetic fields, not by randomly emitted photons or any other function ascribed to QT.

The second claim of applying QT to develop the SEM, made to me personally by a Nobel Laureate in physics, attributes the so-called "quantum tunneling effect" as the means of acquiring the microscopic image by electron tunneling between the specimen and a tiny probe of the microscope. But recently, research at the Naval Research Laboratory revealed that the so-called "quantum tunneling effect" is controlled by a *magnetic field:*

> NRL's Stuart Wolf, who spoke at the APS March Meeting in Los Angeles… described… effects… in which the electrons experience in a multilayered material can be substantially altered by the **magnetic field** within the material, and **spin dependent tunneling**, *in which an electron can move through a normally impenetrable barrier if it has the right spin value.* The movement of an electron in a circuit can also be manipulated by properties other than its charge [13, emphasis added].

Properties of the Spinning Ring Model. Is it possible to develop a model of the electron based on Classical Electrodynamics that agrees with the known characteristics of the electron? Yes. The spinning ring model of the electron has properties that match measured features of the electron.[14] The following sections describe how the spinning ring model was logically *derived* from the electron's measured characteristics.

Balanced Forces. For the electron to be stable, forces on every part of its surface must be in balance. But the electron is a small charged particle, and charges of like sign repel themselves. The model must show why the electrostatic Coulomb force from the electron's charge does not cause its surface to fly apart.

Binding Force. What holds the electron together, keeping charge compressed in a small volume? This "binding force" must be as strong as the repulsive electrostatic Coulomb force. Suppose that elementary particles have the shape of a small sphere as proposed by Abraham and Lorentz. The electrostatic charge would move to the surface of the sphere, being repelled from the sphere's interior by the mutual forces of repulsion between elements of the electron's charge. This provides the particle with a minimum amount of potential energy for a given radius of the sphere. Corresponding to this potential energy is an equivalent mass which must equal the measured electron mass.

Proton Binding Force. Whatever model is suitable for an electron should also be suitable for a proton. Since the proton's mass and mass-equivalent energy is about 1,836 times the electron's mass and energy, the proton sphere would have to be much *smaller* than the electron. ***Compressing** the proton charge to a smaller area gives it more potential energy,* just as compressing a spring to a smaller size adds potential energy. Somehow, the binding force that compresses elementary particles must compress a proton more than the larger electron.

Unsuitable Binding Forces. Which of the recognized forces could possibly act as a binding force to provide an equal and opposite force to the **electrostatic force** of repulsion? Certainly not **gravity,** which is far weaker than the electrostatic force over the same distance. The electron is stable outside the nucleus, beyond the domain of the **strong force,** and the **weak force** is said to cause disintegration; so neither of these forces can provide the electron binding force. This leaves only one other known force that can act as a binding force—**magnetism.**

Magnetic Pinch Effect. Magnetism has the essential characteristic—a force of attraction between parallel current elements. Ampere's law tells us there is a force of *attraction* between two wires carrying current in the same direction. This force is called the "magnetic pinch effect" in order to describe the "squeezing" force exerted on moving charge.

Analysis of a Spinning Charged Sphere. Magnetism occurs only when charge is moving. The strength of a magnetic field is proportional to the charge *velocity*, and the magnetic force exerted on another moving charge is proportional to the *velocity* of the second charge. Now a charged sphere in rotation has its maximum rim velocity at the equator and is compressed by the magnetic pinch force in the equatorial zone.

But at the poles of the sphere there is no tangential velocity and no magnetic pinch effect. This means that the sphere is an unsuitable model for the electron because the electrostatic and magnetostatic forces at its surface can only be balanced at one latitude. For any given rate of rotation, all latitudes of the sphere except one (at the equator) will have an attractive inward force from magnetism that is weaker than the constant outward force from electrostatic charge on the sphere.

Shape of the Electron. This analysis of the spinning charged *sphere* shows that it cannot be stable and is therefore unsuitable as a model for the free electron. The model must have some shape such that a rotation gives all its parts a constant velocity. *Only one possible shape meets this requirement: a very thin ring (i.e.,* the ring must have a thickness radius r that is small in comparison with the ring radius R).

Rotation Rate. The spinning charged ring has a Coulomb force attempting to expand its thickness and a magnetic pinch force attempting to compress its thickness. At one rate of rotation ω, the two forces will be equal in magnitude and the net force on charge at the ring surface will be equal to zero. A calculation shows that the balanced condition occurs when the tangential velocity at the rim of the ring equals the speed of light c. Thus, for stability, the rotation rate must have the value $\omega = c/R$.

Ring Parameters. In addition to holding one unit of charge e on its surface, the ring model has three physical parameters. These are its radius R, its half-thickness radius r, and its rotation rate ω. These four parameters can be selected to match four fundamental characteristics of the ring which are usually considered to be its mass, charge, spin and magnetic moment. However, when the four ring parameters are adjusted to these fundamental characteristics of the electron, the model agrees with the various and sundry properties listed earlier for electrons.

Electric Fields of a Spinning Charged Ring. The spinning charged ring has two electric fields: an *electrostatic field* emanating from its charged surface and a *magnetostatic field* from the ring current loop. While the spatial distribution of energy differs for the two fields, they have two common features: (1) the fields are stationary, being fixed to the location of the ring and (2) the fields do not vary with time and are therefore static. As a result, no radiation of energy into space is possible. If the charge does *not* occupy the ring continuously, as in the *orbiting* electron in the Bohr model of the atom, radiation occurs from the moving charge. *But when the charge is distributed uniformly over the surface of a ring, no radiation occurs, permitting the energy and dimensions of the electron to be stable.*[15] With no radiation of energy, a rim velocity equal to the speed of light is possible and does not violate any known principle of science. Later, it will be shown that this particular velocity is required by electromagnetic theory and observation.

Calculating Ring Parameters. The three physical parameters of the ring can be calculated from three known facts or conditions. The rotation rate ω was obtained from the requirement for dimensional stability, leaving two other parameters, radius R and half-thickness radius r, to be calculated.

Radius of the Electron. The radius of the free electron is easily found from measurements of its magnetic moment μ since $\mu = \pi R^2 I$. Using $I = \omega e/2\pi$ where the rotation rate $\omega = c/R$ provides the relationship between radius and magnetic moment, $R = 2\mu/ec$. The calculation shows the radius of the free electron is 3.86607 x 10^{-13} meters. The radius can also be specified as $R = h/2\pi mc$ so that the circumference of the ring is seen to equal the deBroglie wavelength.[14]

Half-Thickness of the Electron. The potential energy stored in the fields surrounding a free electron has two components: electrostatic energy from the *location* of charge stored on the ring surface and magnetostatic energy from the *rotation* of the electron charge. The energy stored in these fields of potential energy depends upon the half-thickness of the ring, as well as its radius and rotation. The latter two parameters have been determined for the electron, so the half-thickness *r* of the ring can be calculated from the electron's potential energy, $E = mc^2$ where *m* is the measured mass of the electron. By this approach, the half-thickness r of the ring is calculated to be $\ln(R/r) = 8\pi^2 \varepsilon_0 \mu mc)/e^3 + 1 - 3\ln 2$ where $\ln(R/r)$ specifies the ***shape*** of the ring. It has been shown that $\ln(8R/r)$ is approximately equal to π/α where α represents the fine structure constant.[14]

As the previous equation shows, the *shape* of the ring, *R/r,* remains constant—even when magnetic flux links the ring with another nearby particle (*e.g.,* in a nucleus). The ring remains *rigid* because forces acting normal to the surface are much greater (by a factor of about 10^{15}) than forces that establish the ring radius. A calculation shows that the ring is very thin, *r* being much smaller than *R*.

Conservation of magnetic flux. It has been shown that the total magnetic flux ϕ passing through the ring remains constant.[16] By Faraday's *law of magnetic induction,* the ring reduces its radius *R* and thereby adjusts its self-induced flux when external flux is added from a second charged ring.

Planck's Constant. For a spinning charged ring, *the product of electric charge q and magnetic charge ϕ remains constant with the value h (Planck's Constant).*[16] This is true for any system of rotating charge—a relationship that students of J. J. Thomson had to prove.

Since Planck's constant *h* is directly related to the fine structure constant α, the *shape of a ring* may be expressed in terms of either constant. To some, this physical relationship may be more meaningful than the electrical relationship $e\phi = h$. In either case, the reader should recognize that *any theory which predicts a fundamental constant is superior to another theory that uses it but does not predict it.*

Ring Characterization. We may observe here that the ring model of the electron is fully characterized. It's four parameters—one unit of charge distributed over the surface of the ring, and its three physical parameters: rotation rate ω, radius *R*, and half-thickness *r*—have been calculated. These four parameters lead directly to the four fundamental characteristics of the electron as well as several other features of this elementary particle. This spinning ring model of the electron has a size, a shape and a structure.

Magnetic Moment. The radius of the spinning ring was obtained above from observations of the electron's magnetic moment; therefore, the spinning ring model is in agreement with the electron moment.

Spin. The spin, or angular momentum, of an object in rotation is given by the product of three parameters mvR. The ring spins with tangential velocity c at a radius $R = h/2\pi mc$. *The* rest-mass of an electron is almost equally divided between its electrostatic and magnetostatic energies.[14] For the calculation of spin, only the contribution from magnetostatic energy is included, corresponding to the *motion* of charge in the spinning ring. Thus, only one-half of the electron's energy contributes to its "motional mass," and the calculation provides the correct value of electron spin, $\mathbf{p}_s = h/4\pi$. This explanation for only one-half unit of the angular momentum instead of a full unit was first given in 1990 *and is the first explanation of the electron's spin based on reasoning from physical properties.*[14]

Gyromagnetic Ratio. The ratio of magnetic moment to spin is known as the gyromagnetic ratio and is approximately equal to 2 (relative to e/m) because of the equipartioning of electrostatic and magnetostatic energy described above. Actually, the gyromagnetic g-factor has been measured very accurately and found to be a little larger than 2. The physical explanation of this anomaly is found in the fact that the magnetostatic energy is slightly less than the electrostatic energy (see Table 1) and less than one-half of the total rest mass energy of the electron. The magnitude of the magnetic moment depends upon the exact distribution of charge throughout the interior of the ring. In the simplest ring model—a current loop—a negative constant in the equation for inductance of a ring leads to less magnetostatic energy and a smaller magnetic ratio.[14]

Inertial Mass. Russell Humphreys showed that an electric current resists attempts to change its velocity due to the reaction force on the current by the fields generated if the current is accelerated.[17] By a similar analysis, it has been shown that electrostatic charge has an associated inertial mass. In the spinning ring model, the contributions to inertial mass from the charge and current are equal. If the charge is distributed in a thin layer at the surface of the spinning ring, the spinning ring has the same value of inertial mass that has been measured for the electron.

Particle Characteristic. The electron is a particle because it has a definite shape with sharp, well-defined boundaries. It also possesses a precise amount of charge, one unit, and a precise amount of inertial mass corresponding to its size, shape and the potential energy in its electromagnetic fields. These two features, *charge* and *potential energy,* define its particle and material characteristics in contrast to radiated energy (light, gamma rays, *etc.*) which propagates without the presence of charge.

Wavelike Properties. It is well known since the suggestion by deBroglie and verification by Davisson and Germer and by G. P. Thomson that the electron also has a wavelike property. The wave property follows naturally from the ring model which has a circumference equal to the deBroglie wavelength. Furthermore, the ring, being an electric circuit or current loop, has a definite capacitance C and inductance L. The ring functions as a transmission line in a continuous loop with resonant frequency given by $\omega = 2\pi / (LC)^{1/2}$ and a standing wave consisting of electrostatic and magnetostatic fields. The relative velocity between the electromagnetic fields and the ring charge is, of course, the velocity of light c, as required by Maxwell's theory. In order to sustain the standing wave, a multiple or sub-multiple of the wavelength of the standing wave must equal the circumference of the ring so that the ring radius has a constant value $R = h/2\pi mc$.

Spectra. Using the resonance property of the ring, C. Lucas and J. Lucas have shown that the spinning charged ring produces the measured spectral wavelengths from electrons in hydrogen molecules.[18] The ring model accurately predicts the newly discovered wavelengths found by Labov and Bowyer[19] in the extreme ultraviolet region of the spectrum—wavelengths that QT failed to predict.

Refinements. Several refinements to the ring model have been made since it was first proposed by Parson in 1915. Working independently, Iida (1974), Jennison (1979), Bergman and Wesley (1990), Bostick (1991), and Valenzuela (1997) came to similar conclusions. Bostick's last version of the ring model is a helical filament of charge wrapped around the surface of a ring—like a circular solenoid. Even though photographic evidence for the natural existence of a helical structure was obtained in Tokomak experiments using ionized gas particles, was observed in other gaseous plasmas, and was photographed in some lightning bolts, the Bostick refinement needs more theoretical work to determine the precise distribution of charge in the spinning charged ring.

Summary. A physical model of the electron has been derived from logical considerations and four conditions:

1. The electron is composed of one quantum of electrical charge.

2. The forces at the surface of the electron must be in balance.

3. The electron has a magnetic moment slightly larger than one Bohr magneton.

4. The electron has measured mass and equivalent electromagnetic energy.

These four conditions were used to determine the physical and electrical characteristics of the electron in the spinning charged ring model. Although just four conditions were used to create the ring model, it is consistent with various and sundry properties of the electron described earlier. The physical and electrical characteristics of the spinning charged ring electron are listed in Table 1.

The ring model of the electron is a physical model, in contrast to the abstract mathematical description given for the quantum electron. The ring model depends upon well-established laws of electricity and magnetism, and it is a classical electrodynamics model that follows the *law of cause and effect.* It appears to be free from internal contradictions and defects that characterize other models that have been proposed.

Table 1
Properties of the Free Electron

Charge, *e*	1.60218×10^{-19}	Coulomb
Mass, m	9.10953×10^{-31}	kilogram
Magnet moment	-9.2848×10^{-24}	J/T
Radius, *R*	3.86607×10^{-13}	meter
Shape, ln(*R*/*r*)	429.931	-
Rim speed	*c*	meter/s
Rotation, ω	7.75445×10^{20}	rad/s
Current, *I*	-19.773	Ampère
Capacitance, *C*	3.1281×10^{-25}	Farad
Inductance, *L*	2.0891×10^{-16}	Henry
Magnetic flux, ϕ	-4.1309×10^{-15}	Weber
Static energy	4.10312×10^{-14}	Joule
Magnetic energy	4.08412×10^{-14}	Joule

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