A Physical Model for Atoms and Nuclei — Part 4

Blackbody Radiation and the Photoelectric Effect

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Abstract. A physical geometrical packing model for the structure of the atom was developed previously [1-8] based on the physical toroidal ring model of elementary particles proposed by Bergman [9]. From the physical characteristics of real electrons experimentally determined by Compton [10-12] this work derived, using combinatorial geometry, the number of electrons that pack into the various physical shells about the nucleus in agreement with the observed structure of the Periodic Table of the Elements. The constraints used in the combinatorial geometry derivation were based upon simple but fundamental ring dipole magnet experiments and spherical symmetry. From a magnetic basis the model explained the physical origin of the valence electrons for chemical binding and the reason why the Periodic Table has only seven periods.

The toroidal model was then extended to describe the emission spectra of hydrogen and other atoms. Use was made of some of the author's standing-wave experiments with large toroidal springs. The resulting model accurately predicted the same emission spectral lines as the Quantum Model including the fine structure and hyperfine structure. Moreover it went beyond the Dirac and Bohr quantum models of the atom to predict 64 new lines or transitions in the extreme ultraviolet emission spectra of hydrogen that have been confirmed by the Extreme Ultraviolet Physics Lab at Berkeley from its NASA rocket experiment data [13].

In this work *blackbody radiation* and the *photoelectric effect* are explained in terms of the Ring Model and electromagnetic waves. Here the emphasis is on the atom consisting of finite-size electrons acting as containers with quantized internal standing-wave-type structures for absorbing and emitting electromagnetic waves— in contrast to the notion of quantized packaging of electromagnetic energy into particles called *photons.*

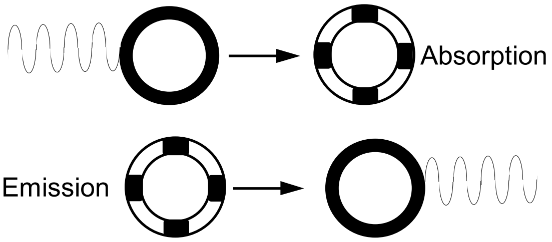

Figure 1.
Absorption and Emission of Radiation by Ring-Electrons.

Top (absorption) — Energy is absorbed from the incoming lightwave by the electron (magnetic induction). Redistribution of charge is shown with electron in a state of excited energy. The actual distribution of charge is more complicated than the drawing shows.

Bottom (emission) — Electron releases energy by radiation of a new wave and another redistribution of charge (emission in accordance with electric induction).

Classical Explanation of Quantum Phenomena. Historically the Theory of Quantum Physics was invented to explain three phenomena, *i.e.* blackbody radiation, the photoelectric effect, and the structure and energy levels of the atom. In the first part of this research based on Bergman's physical model of elementary particles [9], the structure of both the atom and the nucleus was predicted using combinatorial geometry and electrodynamics [1-8]. In this part the research is extended to explain the remaining phenomena that were foundational to Quantum Theory. One outcome of this work is the conclusion that quantum effects are ***not*** due to the Quantum Electrodynamics Theory of point-particles with a quantum of electromagnetic energy called a *photon*, but rather to the internal structure of finite-size electro-dynamic particles. This possibility has always been recognized, but not seriously considered because it was not known how to explain some key experimental data such as the Photoelectric Effect and Blackbody Radiation.

Blackbody Radiation **[8].** In 1901 Max Planck [14] was able to find a mathematical expression that fit the blackbody radiation data. His attempts to work backwards to find the correct physical theory resulted in the birth of Quantum Physics. However, this theory was never fully satisfactory. It was based on the notion that point-charges undergoing simple harmonic motion in the blackbody were absorbing and emitting radiation. This picture led to oscillations of point-electron charges *that were too big to remain in the lattice of the solid.* Also, the empirical laws of electrodynamics were violated by Planck's theory. Both Ampère's Law and Faraday's Law require continuous emission and absorption of radiation for simple harmonic motion of point-electron charges. Finally, the Quantum Theory of blackbody radiation was not compatible with optical reflection, refraction, and diffraction phenomena due to its emission of radiation that is *discontinuous* in time.

The problem with Planck's work — which was to develop a proper scientific theory to predict his mathematical expressions that described blackbody radiation — was that he had an inadequate model for charged elementary particles in nature. He had the notion that elementary particles could be approximated as point-particles. This notion is still found today in Quantum Theories and in Relativity Theory.

Bergman's toroidal "ring" model of elementary particles behaves quite differently with absorption and emission of radiation than is the case for point-particles. Radiation may be continuously absorbed by the ring structure. Since it is a continuous ring structure, the laws of electrodynamics do not require it to immediately re-radiate the energy absorbed [18].

When electromagnetic energy or light is absorbed by the ring, there is a disturbance of the flow of charge around the ring, resulting in oscillations of the electric charge distribution flowing around the ring at the speed of light. These oscillations reflect the wavelength of the light being absorbed. The flow of charge around the ring may be thought of as the superposition of the original continuous flow plus the oscillations of charge resulting from the absorption of various lightwaves (see Figure 1).

The original state of the ring, *i.e.* the continuous flow of charge around the ring, is known as a *stationary state*. No change can be detected over time. Additional stationary states of the ring structure will occur when the oscillations of the charge produced by the absorption of radiation produce standing-waves, *i.e.* the wavelength is exactly an integral number of circumferences of the ring, *i.e.* $n(2\pi r) = \lambda$, $n = 1,2,3,\ldots$ or the circumference of the ring is exactly an integral number of wavelengths, *i.e.* $(2\pi r) = n\lambda$, $n = 1,2,3,\ldots$ When a ring is in a stationary state, the distribution of charge is stable, and the surrounding electromagnetic fields form a standing-wave with an integer number of nodes.

The ring may retain the radiation energy indefinitely. The laws of electrodynamics do not require it to emit any radiation. However, if the ring has a collision or significant interaction with another moving ring, an additional oscillation of the charge density may result making the ring unstable. The laws of electrodynamics now require the ring to radiate. At this point one makes the reasonable assumption that radiation from ring structures may only occur from one slightly excited stationary state to another stationary state.

From Bergman's paper [9, equation 7 and equation 35]

$$E_n = n\frac{e^2}{2\pi \in_o cR}\log_e 8\frac{R}{r} = n\frac{hc}{\lambda} = nh\nu \tag{5}$$

and $n(2\pi r) = n\lambda$, the energy of the stationary states is

$$E_n = \frac{hc}{2\pi R} = \frac{hc}{2\pi\frac{\lambda}{2\pi n}} = nh\nu \quad where\ \lambda\nu = c \tag{6}$$

Although this result is mathematically identical to Planck's result, it is fundamentally different in the following ways:

1. **It does not violate any known law of electrodynamics.**
2. **It does not use an unrealistic point-particle model for the electron, which undergoes simple harmonic motion.**
3. **It does not require an amplitude of electron oscillation that is too large for the electron to remain in the atom.**
4. **Simple harmonic motion of point charges is *not* the physical mechanism involved in blackbody radiation.**

Let us calculate $\rho_T(\lambda)$, *i.e.* the energy density ρ as a function of wavelength λ for a specific temperature T, under the assumption above that the radiation from the ring-electrons only occurs during a transition from one stationary state to another stationary state. The first step is the evaluation of the average energy contained in each standing-wave of wavelength λ or frequency $\nu = c/\lambda$. According to Classical Physics, the particular energy of some wave can have any value from zero to infinity. The actual value is proportional to the square of its average amplitude, *i.e.*

$$\rho \propto \frac{E^2}{4\pi} \tag{7}$$

However, if we have a system containing a large number of identical ring-electrons which are in thermal equilibrium with each other at a temperature T, the classical theory of statistical mechanics requires that the energies of the standing-waves be distributed according to a definite probability distribution whose form is specified by T.

From the *law of equipartition of energy* the average kinetic energy ε of the standing-wave in the rings is

$$\overline{\varepsilon_{KE}} = \frac{kT}{2} \tag{8}$$

where $k = 1.38 \times 10^{-16}$ erg/deg is Boltzmann's constant. For an electromagnetic wave where only the amplitude of the wave executes simple harmonic oscillations, the total average energy is just twice the average kinetic energy, *i.e.*

$$\overline{\varepsilon} = kT = \frac{\sum_{n=0}^{\infty} nh\nu\, e^{-nh\nu/kT}}{\sum_{n=0}^{\infty} e^{-nh\nu/kT}} = \frac{h\nu}{e^{-h\nu/kT} - 1} \tag{9}$$

And the Boltzmann probability of finding the wave in an energy state between ε and ε + dε for a system containing a large number of ring-electrons with waves is

$$\mathrm{P}(\varepsilon) = \mathrm{A}\, e^{-\varepsilon/kT} \tag{10}$$

The average energy of a wave is given by

$$\overline{\varepsilon} = \frac{\int_0^{\infty} \varepsilon\, \mathrm{P}(\varepsilon)\, d\varepsilon}{\int_0^{\infty} \mathrm{P}(\varepsilon)\, d\varepsilon} \tag{11}$$

However under our assumption that radiation can only occur from rings with stationary state charge distributions, we must recalculate ε by replacing all integrals over ε by summations*, i.e.*

$$\overline{\varepsilon} = \frac{\sum_{n=0}^{\infty} \varepsilon_n\, \mathrm{P}(\varepsilon)}{\sum_{n=0}^{\infty} \mathrm{P}(\varepsilon)} = \frac{\sum_{n=0}^{\infty} \mathrm{A}\, \varepsilon_n\, e_n^{-\varepsilon_n/kT}}{\sum_{n=0}^{\infty} \mathrm{A}\, e_n^{-\varepsilon_n/kT}} = \frac{\sum_{n=0}^{\infty} nh\nu\, e^{-nh\nu/kT}}{\sum_{n=0}^{\infty} e^{-nh\nu/kT}} = \frac{h\nu}{e^{h\nu/kT} - 1} \tag{12}$$

Now

$$\rho_T(\nu)d\nu = \frac{\bar{\varepsilon}N(\nu)d\nu}{V_{\text{ring}}} \quad \text{where } V_{\text{ring}} = (2\pi R)\pi r^2 \tag{13}$$

where $\mathrm{N}(\nu)$ is the number of allowed frequencies in the frequency interval ν to $\nu + d\nu$. It can be shown that $\mathrm{N}(\nu)d\nu$ is independent of the shape of the ring and depends only on its volume $V = 2\pi R(\pi r^2)$, [15, p. 57] *i.e.*

$$N(\nu)d\nu = \frac{8\pi(2\pi R)(\pi r^2)\nu^2 d\nu}{c^3} \tag{14}$$

Thus

$$\rho_T(\nu)d\nu = \frac{h\nu}{e^{h\nu/kT}-1} \times \frac{8\pi(2\pi R)(\pi r^2)\nu^2 d\nu}{(2\pi R)(\pi r^2)c^3} = \frac{8\pi\nu^2}{c^3} \times \frac{h\nu}{e^{h\nu/kT}-1} \tag{15}$$

Transforming to the variable λ where $\nu = c/\lambda$, $d\nu = -(c/\lambda^2)d\lambda$, and $\rho_T(\lambda)d\lambda = \rho_T(\nu)d\nu$

$$\rho_T(\lambda)d\lambda = \frac{8\pi hc}{\lambda^5} \times \frac{d\lambda}{e^{hc/k\lambda T}-1} \tag{16}$$

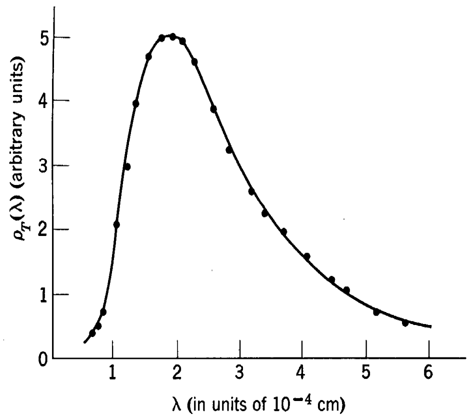

Figure 2.
Blackbody Spectrum

This is mathematically the same as the blackbody spectral distribution derived by Planck (see Figure 2).

However, it has a very different physical interpretation, and it does not violate the laws of electrodynamics.

Photoelectric Effect **[8].** The photoelectric effect in which electrons are emitted from the surface of a metal was discovered by Hertz, Hallwachs, Elstey and Geitel [16] in 1887. A modern form of their apparatus is shown in Figure 3. The glass tube contains a polished electrode, called the photocathode, and a second electrode in the form of a perforated metal plate. The two electrodes are maintained at a potential difference of a few volts with the second electrode being positive with respect to the photocathode. When

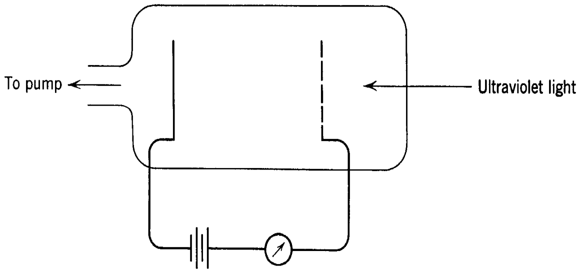

Figure 3.
Photoelectric Cell

ultraviolet light passes through the perforated second electrode and is incident upon the inner surface of the photocathode, a current is observed to flow through the tube. This phenomenon is called the photoelectric effect. The effect persists even when the tube is evacuated to very low pressure, implying that gaseous ions are not the carriers of the current.

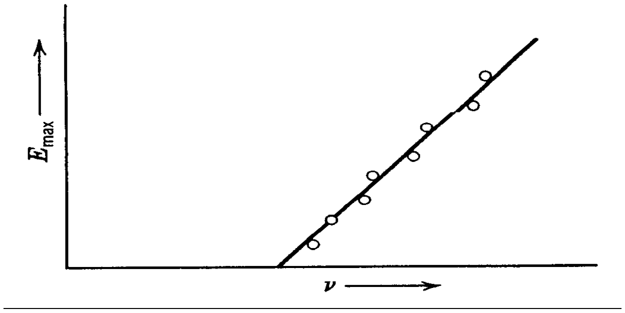

Figure 4.
Kinetic Energy of Photoelectrons
As a Function of Frequency
[15, *pp.* 79-81]

In 1905 Einstein [17] announced a Quantum Theory of the photoelectric effect which was closely related to Planck's Quantum Theory of blackbody radiation. He reasoned that Planck's requirement that the energy of the electromagnetic waves of frequency ν in an ultraviolet light source can only be 0, $h\nu$, $2h\nu$, ... $nh\nu$ implies that in the process of going from energy state $nh\nu$ to energy state $(n-1)h\nu$ the source would emit a burst of electromagnetic energy of $h\nu$.

Einstein assumed that such a burst of emitted energy was initially localized in a small volume of space; and that it remains localized as it moves away from the source with velocity *c*, instead of spreading out in the manner characteristic of all observed moving waves. He assumed that the energy ϵ of such a bundle or quantum of energy is related to its frequency ν by the equation

$$\in = h\nu \tag{17}$$

He also assumed that in the photoelectric process one of the quanta is completely absorbed by a point-electron in the photocathode.

According to Einstein the absorption of a quantum by the electron gives it an additional energy of $h\nu$. If this energy is greater than the energy E which the electron must expend in escaping from the atom to which it is bound inside the photocathode plus the energy W required to reach the surface of the photocathode, then the electron escapes from the photocathode. The kinetic energy of the electron after escaping from the photocathode will be equal to $E = h\nu - \Delta E$. For an electron originating at the surface E will just be equal to W and E will have its maximum value where W is a constant that depends on the type of atoms in the photocathode (see Figure 4).

$$E_{\text{max}} = h\nu - W \tag{18}$$

One of the weaknesses of Einstein's theory was that it could not physically describe the absorption process in terms of physical changes in the internal structure of the electron. The physical mechanism for absorption could not be explained. Only the mathematical equations describing the process could be motivated. This is the same problem that Planck had with his theory of blackbody radiation.

In the Ring Model, when a free electron is captured by an ionized atom, it gives off light as it approaches the ion and changes from one stationary state (standing-wave charge configuration) to the next. The size and internal charge density is changing in agreement with the balance of electric and magnetic forces. In order to free the electron from the ion, it is necessary for the electron to absorb at least as much electromagnetic energy as it radiated off when it was captured earlier. Although the electromagnetic energy was radiated away from the electron in a series of long wavelength electromagnetic waves, it cannot be freed by absorbing a series of low-energy long-wavelength electromagnetic waves, because of the short lifetime and quick decay of these excited stationary states back to the minimum energy bound state due to thermal excitation. Thus, for all practical purposes, all the energy to unbind the electron must come by absorption of only one wave-cycle. That is why there is a minimum value of the wave energy being absorbed to free the electron. The absorption can not be a multi-step process.

In the physical Ring Model the absorption of radiation produces changes in the current density in the ring such that it has Fourier components synchronous with the absorbed electromagnetic wave (see Figure 1). For the same reason a ring-electron can only emit radiation of such wavelengths as it has synchronous Fourier components in its current distribution [16].

Before the finite-size Ring Model of the electron was developed with its strong magnetic coupling in molecules and crystal lattices, the classical wave theory of light had a serious problem in describing the short (10^{-9} sec) time required for a point-electron to absorb enough energy to escape from the atom. If one assumed that the point-electron orbit was on the order of the size of the atom (10^{-8} cm), and one calculated the incident energy on the area of the orbit, one can obtain the time required for the photoelectron to absorb the required 10^{-12} ergs from ultraviolet light. The time calculates to approximately 100 seconds. Experiments performed in 1928 by Lawrence and Beams using a very weak ultraviolet light source set an upper limit on the delay before electron emission of about 10^{-9} sec [15].

Now there is a big difference between the model of the point-electron orbiting the nucleus and the finite-size ring-electron model. The ring-electron is close to the size of the Bohr orbits of the point-electron. However, the ring-electrons are strongly coupled to one another in the atom, in the molecule, and in the lattice. Figure 5 shows a carbon-dioxide (CO_2) molecule which is illustrative of the strong magnetic coupling of electrons in magnetic flux loops. All the

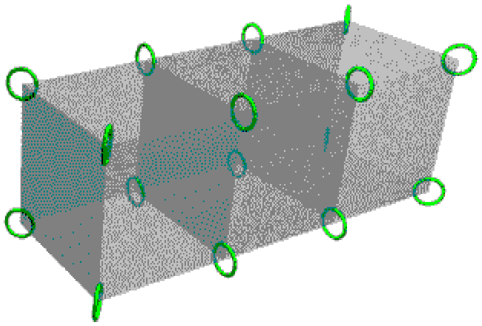

Figure 5.
Carbon-Dioxide Molecule showing Magnetic Coupling of Ring-electrons.

ring-electrons on the top and bottom of the cubic structure are bound together with a single flux loop (one for the top and one for the bottom)

The photoelectric effect is only observed in metals. Metals have macroscopic crystal lattice domains. In these lattice domains large numbers of electrons are strongly coupled in large magnetic flux loops. The number of coupled electrons is close to the order of Avogadro's number — about 10^{23} molecules/gm-molecular weight. These strongly coupled electrons form a linear array antenna that has little trouble capturing enough energy to free some electrons in 10^{-9} sec. Thus the finite-size ring-electron model with strong magnetic properties is able to explain all the experimental data that the classical point electron model failed to explain.

Conclusions. The classical electrodynamics ring model of the electron allows a superior explanation of the emission spectra of atoms, blackbody radiation, and the photoelectric effect. It is superior because

1. **It explains the 64 observed extreme ultraviolet spectral lines of hydrogen which are unexplainable in terms of the Dirac quantum theory of the atom.**

2. **It explains blackbody radiation without violating Faraday's law and Ampère's law requiring oscillating point-particles to continuously radiate energy.**

3. **It is compatible with optical reflection, refraction, and diffraction phenomena since its emission of radiation is continuous while Quantum Theory is discontinuous.**

4. **It explains the Photoelectric Effect and Blackbody Radiation in terms of a physical model of absorption and emission of radiation that is completely missing in Quantum Theories of point-particles.**

For these reasons the classical electro-dynamic ring model of the electron and its resulting theories of the atom and nucleus are superior to the Quantum Theory. Quantization occurs in the container of the finite-size electron due to its internal structure. *There is no elementary particle or quantum packages of energy called the photon.* The quantum explanations of atomic emission spectra, blackbody radiation, and the photoelectric effect are all defective. If the logical rules undergirding the scientific method since the days of the ancient Greeks had been followed by the scientific community [19-21], quantum theories would have never been recognized as valid scientific theories.

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Correspondence of Charles W. Lucas, Jr. and David L. Bergman on The Photoelectric Effect

Bergman: One sentence on page 7 especially caught my attention: "Thus, for all practical purposes, all the energy to unbind the electron must come by absorption of only one wave-cycle."

I think your explanation of the Photoelectric Effect is correct. However, I think all the energy that releases an electron would actual transfer in one-half of a cycle, and that the second half cycle of an incoming wave would not be relevant. When only *energy* is considered, without looking at the *force mechanisms of induction*, the finer points of the Photoelectric Effect are not explicitly stated.

Perhaps a more detailed explanation of the Photoelectric Effect could be developed for a later paper. I think we could show that the wavelength of incoming radiation must be close to the Compton Wavelength and the circumference of the ring-electron. Then, by the *laws of induction*, the ring (acting as a receiving antenna) could absorb energy from the radiation only when that radiation was in a narrow range of wavelengths. The lower limit of energy and frequency is well-known (as you show by a graph in Figure 4). I once was told that coherent radiation from a laser source would *not* liberate an electron, presumably because the frequency is too high. This seems reasonable since very high frequency would produce alternating forces between the metal and electron that reverse in direction before an electron is liberated. Such a conjecture on my part would have more validity if there is supporting experimental data that shows the entire range of frequencies that liberate an electron.

My conjecture about the mechanism of inducing a liberating force must also be verified by the experimental evidence that *radiation intensity* is not a factor in liberating an electron. Here, it seems to me, a distinction must be made between coherent and non-coherent radiation. I suspect that liberation may be a function of radiation intensity *only when a coherent source is used.*

Lucas: Your comments on coherent versus non-coherent radiation are well taken. This may be a way to distinguish between the quantum theories and the Ring Model. We do not have to actually do these experiments if we can find some published results. The quantum theories should get the same result with coherent or incoherent radiation, but the Ring Model would be more sensitive showing a difference.