Classical Explanation for Atomic Phenomena*

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This paper makes contributions towards classical explanation for the stable paths of electrons around nuclei, and for radiation that occurs in connection with the de-excitation of excited electrons in atoms.

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1. Introduction

The fact that an orbiting electron does not collapse into the nucleus of its parent atom has thus far been considered a major obstacle to a classical interpretation of the behavior of orbiting electrons. Quantum mechanics avoids the very problem by discussing the probability of finding the electron, a method that confessedly has been very fruitful in the exploring the behavior of elementary particles. Nonetheless, why should those two approaches necessarily be regarded as each others´ enemies?

In this paper it is shown that the classical mechanistic approach is still capable of explaining the eternal, circular movement of an electron around a nucleus. It is possible if reformulating the laws of action involved, returning to the simple electrostatic model, based upon Coulomb´s law (1785, 1771).

Further, in this paper it is also discussed, how electromagnetic radiation due to the de-excitation of excited electrons, orbiting around a positive nucleus, can be explained classically, as a sudden peak in the otherwise zero electric field, due to the inwards spiralling movement connected to the de-excitation. The concept of a distinct particle, the 'photon' is thereby rejected.

2. The Stability Problem

It is usually claimed within physics that a continuously orbiting electron must give rise to radiation, and hence the classical model of a planet-like electron must accordingly be abandoned in favour of Quantum theory.

Nothing bad shall be said here about Quantum theory, but the classical model of the orbiting electron may still be useful, provided no energy is being consumed during its revolution around the positively charged nucleus.

In order to succeed in defending the classical model of an atom with an orbiting electron, it is crucial to show that no energy is being lost during its revolution. If no energy is lost, namely, an eternally circular movement is physically possible.

3. Why an Orbiting Electron Does Not Radiate

In case of circular motion at constant speed, it has to be recalled from mechanics that the acceleration vector is directed radially outwards inwards from the center of mass, thus being perpendicular to the velocity vector of the electron, and hence no work is being done upon it, and it remains orbiting eternally in its circular path. This proof is apparently consistent with the assumption that an orbiting electron does not radiate while remaining in a stable, circular path around a positive nucleus.

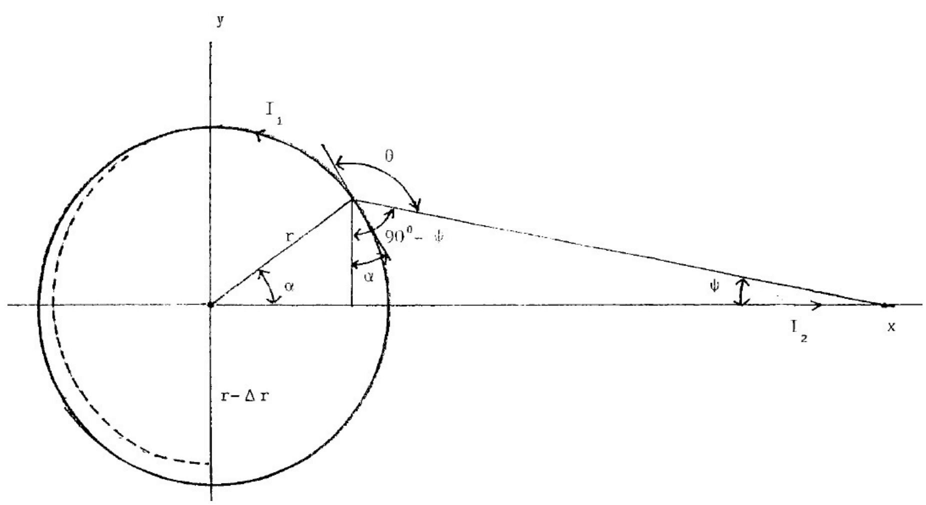

Figure 1. Model atom interacting with a point of observation. Dashed line corresponds to the case of de-excitation of an electron.

The mathematical treatment of the two (what 'two' are you talking about?) cases is performed in the Appendix (What Appendix? Is it Section 7?).

Due to the periodic movement of the electron, it would be claimed that at far distances the electric field would vary due to the continuously changed distance to (it's not oscillation along the line of sight that makes radiation; it's transverse oscillation) the orbiting electron. Of course, this is true, but the change of that distance of the order of one atom diameter can be neglected in comparison with the distance to any point of measurement. Hence, the net electric field due to a stable, electrically neutral atom, must be zero.

4. When Radiation Occurs

Concerning the phenomenon of radiation, a classical explanation would be possible, if only it were possible to define the forces and where the energy losses occur in the system consisting of a positive nucleus and a surrounding, orbiting electron. This means nothing else than that the physics of a 'photon' can be defined.

Radiation would instead appear when an excited electron gets de-excited and jumps down to a lower energy level. That jump, however, must take some time, though short, and during that time interval the motion has a radial component, directed towards the center of mass, and hence there is energy loss due to the non-vanishing scalar product between the force and the velocity vectors.

In the following analysis it will be shown that at far distances from the atom there will be a non-vanishing electric field, during the process of de-excitation of an orbiting electron. In order to simplify the analysis it will be assumed that there is a basically inwards spiralling movement during the de-excitation.

It will also be shown, why there is no electric field in the case of a stable circular movement.

If first analyzing the case of a stable, circular electron orbit, it is convenient to choose two opposite points of that circle, situated on a straight line, perpendicular to the direction to the point of observation. If looking at all possible pairs if points of a complete circle orbit, every contribution to the electric field (or rather electric force, since only forces are being measured) cancel exactly, and hence, no electric force at all appears due to an orbiting electron in that case.

The expression for the electric force is according to a paper previous to this paper (Ref 1). According to that same paper, magnetic fields do not exist at all, and hence, neither electric nor magnetic force can be derived from a system, consisting of a positive nucleus and an electron orbiting in a stable, circular path around the nucleus.

This is - of course - completely in accordance with experience. What is new is that it has been given a classical, mechanistic explanation.

If looking at the case of the de-exiting, spiralling movement, it can easily be seen that if adding the contribution to the electric force due to two opposite points of a spiral, it is no longer zero, since the two cosine terms differ slightly from each other. That difference gives rise to a net force term, proportional to the difference in the radial distance from nucleus to electron due to two oppositely situated points. And , since, it takes a little time for the electron to move from one point to the other, due to the orbiting speed, the electric force per time unit (i.e. the mechanical effect) is indeed proportional to the orbiting frequency. And, finally, if making the scalar product between effect and velocity, the energy is attained. Hence, it has been shown that the energy being lost during the de-excitation of an orbiting electron is given a classical, mechanistic explanation.

The work with making a sum (*i.e.* integral) of all such contributions to the electric force will be avoided here. Recalling the mean value theorem of the integral calculus, it can be realized that the integral will contain the basic mathematical features of the integrand: an electric force proportional to the inverse square distance and to the orbiting frequency. Needed is thereafter to attach a 'coupling constant' in order to make the expression fit with measurements. But performing any of the proposed measures would go far beyond the resources defined to this paper and would need the collected resources of a scientific department.

Nonetheless, it has been proved that a classical explanation to radiation is possible, thereby refuting the exclusive claims of quantum mechanics to give the only possible explanation.

5. What Then is a Photon?

Using the above results, it has been seen that the electric force due to an de-exciting orbiting electron can be classically explained. Now modern physics claim that there is released a photon in connection with that de-excitation process. And that 'photon' has the property to have no rest mass. The photon has short-to-say been given an a priori defined existence.

But it is also possible to use the above result in order to resolve the paradox of the photon. If recalling that the de-excitation process ends after a time, the energy due to the attained energy per time must be limited. And, since the time interval is indeed very short, it is convenient to use the Dirac Function in order to describe the process. The orbiting frequency appears as a sine function of time, attached to the Dirac term.

This means that the 'wave property' of light (radiation) corresponds to a .certain term of one unified mathematical expression, the varying one. The particle property then corresponds to the 'Dirac term'.

The whole situation would best be compared to an AM radio signal, a Dirac function in this case modulating a carrier, *i.e.* the orbiting frequency of the electron. That discussion will be fulfilled in Section 8 below.

6. Preliminary Conclusion

It's mainly up to the reader to draw conclusions. It nonetheless seems to be inspiring that the classical, mechanistic model of physics still remains capable of dealing with problems that one thought the quantum models were exclusively capable of doing.

7. Fundamantal Reference Paper

In this paper a fundamental description is being given to, how the author uses the concept of electrostatic force, as it is being applied to currents That is very basic to the further discussion, and the reader is accordingly recommended to follow the discussion in that paper. Among others the expression for the

force between two currents is being derived therein. The force is given below for the convenience of the reader.
Chinese Journal of Physics, VOL,35, No 2, April 1997, pp 139-49, Eq.25: http://psroc.phys.ntu.edu.tw/cjp

$$d^2\mathbf{F} / dx'dx^2 = \mu_0 I^1 I^2 \cos\theta \cos\psi \, \mathbf{u}_R / 4\pi R^2 \tag{1}$$

7. A Detailed Mathematical Evaluation of the Electric Force

A continuously, homogeneously distributed charge can be regarded as if all the charge was situated in the middle of the charges, at one point. Simultaneously, a point charge might be replaced by such a distributed charge, thereby causing no change in the derived electric or other fields. In the case of an orbiting electron, it would be convenient to distribute the point charge of the positive nucleus along that same orbit.

In that case, one could compare the situation with an electric conductor, filled with moving electrons and immobile positive metal ions. In an earlier paper by this author (Ref. 1) an expression for the electric force between two electric currents is derived, and that expression must then by principle be applicable also to the 'atom current'.

In the case of radiating atoms, the radiation is registered by an observer by means of a corresponding excitation due to the force mechanism. According to the Maxwell concept there is defined a 'Poynting vector' in order to account for the work the radiation causes to be done, i.e. transferred energy. In the model of this author, the work can be related to Coulomb's law.

In the following figure necessary angles are defined in order to be able to write down the electric force between two atomic 'currents'. One easily attains the following relation between the angles by reason of geometry:

$$\theta = \pi - \left[(\pi/2 - \psi) - \alpha\right] = \pi/2 + \psi + \alpha \tag{2}$$

and hence

$$\cos\theta = -\sin(\psi + \alpha) \quad . \tag{3}$$

Using the geometric definitions and

$$\psi = \operatorname{atan}\left(\frac{r\sin\alpha}{x - r\cos\alpha}\right) \tag{4}$$

it is possible to rewrite Eq. (3) into

$$\cos\theta = -\sin\left[\operatorname{atan}\left(\frac{r\sin\alpha}{x - r\cos\alpha} + \alpha\right)\right] \tag{5}$$

In order to simplify the analysis, choose to analyze the contributions to the electric force from pairs of points, situated opposite to each other on a straight line, perpendicular to the direction from the atom to the point of observation, and restrict the analysis to the pair of points at angle $\theta = \pi/2$. Namely, if the contributions cancel exactly, they will do for all other points of the circle, and hence the total force equals zero. Contrarily, if it does not cancel, by geometrical reasons it will not cancel for any other pair of points and the total force would be written as an integral of all these contributions. Using the mean value theorem of Integral calculus, one would realize that the total integral is basically proportional to the mathematical function to be integrated, times the length of the electron orbit. But that last point is unnecessary to evaluate in this connection. Since the intention is just to prove that the new model is physically possible, exact values can at this stage be replaced by coupling constants.

At the angle $\alpha = \pi/2$ one then attains

$$\cos\theta = -\sin\left[\operatorname{atan}(r/x) + \pi/2\right] = -\cos\left[\operatorname{atan}(r/x)\right] \tag{6}$$

or, since

$$y = r\sin\alpha \tag{7}$$

one may as well write

$$\cos\theta = -\cos\left[\operatorname{atan}(y/x)\right] \tag{8}$$

or even simpler

$$\cos\theta = -x\Big/\sqrt{x^2 + y^2} \tag{9}$$

Generally, however, $\cos\theta$ cannot be written that simply, as will be realized by looking at Eq. (2) above.

In order to be able to see the consequences of Eq. (1), it remains even to develop a similar expression for $\cos\psi$. Using Eq. (5) gives

$$\cos\psi = \cos\left[\operatorname{atan}\frac{r\sin\alpha}{x - r\cos\alpha}\right] \tag{10}$$

Evaluating again for $\alpha = \pi/2$ gives

$$\cos\psi = \cos\left[\operatorname{atan}(r/x)\right] \quad . \tag{11}$$

Hence, for this angle

$$\cos\psi = \cos\theta \tag{12}$$

and the electrostatic force according to Eq. (1) becomes basically proportional to $-\cos^2\theta$.

Turning to the opposite point of the circle, stationary orbiting case, the angle θ changes 180º, while ψ remains unchanged, as well as all other variables, which means that the electrostatic force changes sign, but not amplitude, compared with the preceding case. Adding these two contributions gives a zero result. This means that a stable, electrically neutral atom does not affect another such atom with any electrostatic force.

But if at hand is a de-exciting electron, the path follows the dashed curve, and the second point of the circle moves inwards. The direct consequence is that Eq. (9) must change for that point to

$$\cos\theta' = \frac{x}{\sqrt{x^2 + (y - \Delta y)^2}} \tag{13}$$

and also in this case

$$\cos\psi = \cos\theta' \tag{14}$$

After a series expansion, one attains

$$\cos\theta' = 1 - \tfrac{1}{2}\frac{y - \Delta y}{x} + O(y / x^2) \tag{15}$$

and
$$\cos\theta' \cos\psi' = 1 - \frac{y - \Delta y}{x} + O(y / x)^2 \tag{16}$$

If neglecting the change also in the distance R to the point of observation, as a first approximation the contributions from the two oppositely situated points of the – spiral now – may be straightforwardly added, thereby using Eq. (9) and (12) above, if realizing that the corresponding series expansion for the first point gives

$$\cos\theta \cos\psi = -1 + y / x + O(y / x)^2 \tag{17}$$

Thus, summing Eq. (15) to Eq. (16) gives the total force, expressed on differential form,

$$d^2\mathbf{F} / dx^1 dx^2 \text{ basically proportional to } \Delta y / x\,. \tag{18}$$

This procedure might be repeated by integrating all pairs of points, on each half-circle, thus only creating a term proportional to Eq.(18) above. Hence, the claim of Eq (18) remains valid.

Since the electron is orbiting with a frequency f and with a limited speed, one may as well claim that the force is proportional to f. Further, since the de-excitation process endures during a restricted time interval, the work being done by this force is limited, or one may as well say that the transmitted energy is proportional to f, and limited.

8. A Proportionality

This Section comments further on Eq. (18). It should be mentioned that before this term was computed the force had already been shown to be proportional to $1 / R^2$; see Eq.(1), and the variable R is for convenience held equivalent to x, as defined in Fig. 1. Hence, the force, expressed as is finally shown to be proportional to $\Delta y / R^3$

$$d^2F / dx^1 dx^2 \propto \Delta y / R^3 \quad , \tag{19}$$

where Δy has already been shown to be proportional to the frequency f of the orbiting electron.

When discussing thus emitted light quanta, one uses the concept of energy, not work.

And, since energy is equivalent to the integral of work, one has to integrate the work function with respect to the radial distance from the atom, emitting the light quanta.

Thus integrating $\Delta y / R^3$ gives as result a function proportional to $\Delta y / R^2$., *i.e.* Energy

$$E \propto \Delta y / R^2 \tag{20}$$

This property it does however share with the Poynting energy vector, ref. [3].

Hence, it has been shown that using the classical electrostatic model, applying it upon an electron orbit, it is possible to account for the spatial as well as the frequency behavior of the energy of light quanta.

Then there will arise a deep problem: If the classical model can account for an energy with the same properties as that of the Poynting vector, shall one add these two ideas to each other or reject one of them. By normal practice it ought to be better to choose the first one, which is based on the most simple assumptions.

Favorable to the classical approach is evidently, that the force is directed straight between the emitting atom and the receiver, according to Coulomb's law, which implicitly also means that the electric field is aligned with the line of action, whereas the Poynting vector is constructed through making a cross product of two to each other perpendicular vectors, where both the electric and the magnetic fields are also perpendicular to the direction of action, defined by the Poynting vector.

9. How does one Describe Mathematically the Process of De-Excitation ?

In the preceding sections it has been motivated, how the classical electron model, based strictly upon Coulomb's law, is able to account for the typical inverse square dependence of the energy, due to the de-excitation of an orbiting electron. It might also be of interest to give a mathematical description of the force and the energy respectively, due to the de-exciting electron. Eq. (19) and (20) above describes the result.

Applying then the time dependence will favourably begin with realizing that the electron may be assumed to be orbiting with a constant frequency , hence giving rise to a term sin ω t, which the force term (1) will be multiplied with.

The process, during which the electron is spiralling inwards, towards the nucleus, produces a net radial inwards displacement of magnitude Δ y during one half revolution, which accordingly takes place during a time interval equal to $1 / 2f$, or, using the angular frequency just defined, π / ω . Assuming that the total radial displacement will be

$$Dy = 2n\Delta y \tag{21}$$

where n is the amount of revolutions for this to take place, one accordingly will get the following time dependence expressing the collapsing movement:

$$f(t) = Dy / 2n - 2\pi\, t / \omega\, \mathrm{f(t)} \quad . \tag{22}$$

In order to attain the complete time dependence of the electrostatic force, Eq.(1) will accordingly be multiplied with $f(t)\sin\omega t$.

Restricting ourselves to the expression for the energy, one thus obtains:

$$E \propto \frac{D \cdot y}{2n} - \frac{2\pi}{\omega} t \cdot \sin\omega t \cdot 1 / R^2 \tag{23}$$

Another description might be suitable as well, since it can be assumed that the de-excitation takes place during an extremely short time. In such cases the Dirac function can be a reasonable mathematical tool, aimed at clarifying the principal behaviour.

Thus assuming that the total radial displacement is $D \cdot y$, taking place at an infinitely short time interval, one could favourably write

$$f(t) \approx D \cdot y \cdot \delta(t) \quad . \tag{24}$$

Hence, the expression for the energy simplifies to:

$$E \propto D \cdot y \cdot \delta(t) \cdot \sin\omega t \cdot 1 / R^2 \quad . \tag{25}$$

10. Judgment on the Above-Attained Result

In order to better understand the conceptual content of Eq. (25), on favorably observe the product of two of each other independent time functions, namely the dirac function and the sine function.

From telecom theory it is elsewhere well-known that a product of a sine with another time function often is describing a modulated carrier wave. Here a dirac function is allowed to 'modulate' the carrier. What physical significance is that expressing?

An answer to be proposed is that the extreme shortness, though a constant integral value, of the Dirac function well corresponds to the 'particle' or 'photon' property of light, and the sine function to the frequency of that light.

Hence, the 'particle-wave' dualism of light has got a mathematical description, corresponding to a classically described de-excitation movement of the electron.

References

[1] Chinese Journal of Physics, VOL,35, No 2, April 1997, pp 139-49, Eq. 25; http://psroc.phys.ntu.edu.tw/cjp

[2] The VIII International Scientific Conference, August 16-20, 2004, S:t Petersburg, Russia, Baltic State technical University, Russian Academy of Applied Sciences and International Slavic Academy of Sciences, Education and Arts, pp. 111-118, attached in its original manuscript form above.

[3] John David Jackson, Classical Electrodynamics, Third Edition, John Wiley & Sons, p. 665, Eq. (14.18) and (14.19)