The Seeming Mystery of the Electron:

There is no mystery! The electron can be classically understood!

Since the middle of the 1920's physicists have been struggling to understand the electron.

From experiments it was concluded that the electron is a structure-less point-like object, which has its entire mass in this extension-less centre. On the other, hand the electron shows properties which normally result from an extended structure, namely an angular momentum (spin), a magnetic moment, and some kind of an internal oscillation.

In 1928, when Paul Dirac presented the wave function ("Dirac Function") of the electron, it became obvious that there must be not only an internal oscillation but also an internal motion with the speed of light. When Erwin Schrödinger found this as an outcome of the Dirac Function, he felt very uncomfortable about it. He called the phenomenon in German "Zitterbewegung" (zbw) which means some kind of an irregular oscillation.

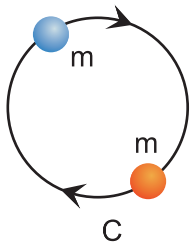
Subsequently the physicists allocated this intrinsic contradiction of the electron's different properties to the common sense understanding, that the electron is subject to quantum mechanics and as such not accessible by human imagination.

However, there is a solution whose understanding relies entirely on the application of the classical laws of physics and which is free of contradictions: If it is assumed that the electron is built by two constituents which are mass-less, then this assumption conforms to all aspects of the experimental investigations. And it provides the correct relations for the parameters of the electron: its mass, its constant angular momentum (spin), and its magnetic moment.

The assumption used above has been generalised for all elementary particles as a physical model, which has the name "Basic Particle Model".

1 Introduction

In the Basic Particle Model every elementary particle is built by 2 mass-less constituents, which orbit each other with the speed of light *c*. The frequency of the circulation is the deBroglie frequency (Figure 1.1).



mass m = 0

circulation = de Broglie frequency

Figure 1.1: Structure of an Elementary Particle

The mass of the entire particle follows from the fact that every extended object has necessarily an inertial behaviour, i.e. a mass.

2 General Particle Properties

2.1 The Mass to Size Relation of a Particle

The circular motion of the basic particles within an elementary particle has the orbital frequency

$$\nu = \frac{c}{2\pi \cdot R} \tag{2.1}$$

where c is the speed of light and R the radius of the elementary particle.

According to the Basic Particle Model, this frequency ν is the de Broglie frequency.

Eq. (2.1) can be written also as

$$\omega = \frac{c}{R} \tag{2.2}$$

using the circular frequency $\omega = 2\pi \cdot \nu$.

If we take the empirical result

$$E = \hbar \cdot \omega \tag{2.3}$$

and the well known relation

$$E = m \cdot c^2 \tag{2.4}$$

and insert both into (2.2) we get

$$m = \frac{\hbar}{c \cdot R} \tag{2.5}$$

for the relation between the radius R of a particle and its mass m.

Remark: This is only a short formal deduction for equation (2.5). The detailed deduction, which justifies the use of eq. (2.2) and eq. (2.3), is given in the context of the 'Origin of Mass'.

2.2 The Magnetic Moment

Next we will recall the classical relation for the magnetic moment of a particle.

The magnetic moment μ of a loop current is classically:

$$\mu = i \cdot \pi \cdot R^2 . \tag{2.6}$$

The loop current *i* within a particle of one elementary charge e_0 is simply:

$$i = \nu \cdot e_0 . \tag{2.7}$$

Using now eq. (2.1) for ν there follows:

$$\mu = \frac{c \cdot e_0 \cdot R}{2} . \tag{2.8}$$

If now *R* is inserted from eq.(2.5) the magnetic moment turns out to be

$$\mu = \frac{\hbar \cdot e_0}{2 \cdot m} . \tag{2.9}$$

For the electron this is the 'Bohr Magneton'.

Please note that this important equation is deduced here classically. Historically, attempts to deduce the magnetic moment of the electron in a classical way were made in the first half of the 20th century. These attempted deductions used the electromagnetic energy within the electron in order to find a relation between its magnetic moment and its mass. The result of this calculation was wrong by a factor of 2. Later the correct relation was deduced by use of the Dirac function of the electron. From this later success it was concluded that the electron can be correctly understood and described only by quantum mechanics.

Eq. (2.5) can now be used to calculate the size of the electron.

If the parameters

$$m_e = 9.11 \cdot 10^{-31} kg$$

$$c = 2.998 \cdot 10^{8} m/s$$

$$\hbar = 1.0546 \cdot 10^{-34} Nms$$

are inserted in eq. (2.5) the result is for the electron

$$R_{el} = 3.86 \cdot 10^{-13} m .$$

This is an unfamiliar result because literature states that any extension of an electron of this order is ruled out by the experiments. This seeming conflict does, however, in fact not exist as explained further down.

If in eq. (2.9) the mass of the electron is inserted, then the magnetic moment of the Bohr magneton

$$\mu_{el} = 9.273 \cdot 10^{-24} Amp * m^2 . \tag{2.10}$$

results from it.

We have to mention here that the magnetic moment of the electron is not exactly the Bohr magneton but slightly greater by a portion of ca. 10^{-3}. The conventional physics (QED) give as a reason vacuum polarization effects around the electron. - It is the only reference to QM which we presently have to use here in order to explain this feeble difference.

2.3 The Angular Momentum (Spin)

Equation (2.5) can be reordered to

$$m \cdot R \cdot c = 1 \cdot \hbar \qquad (2.11)$$

The left side is the formal definition of the angular momentum for *v* = *c*.

The right side fulfils the expectation into the spin of an elementary particle in so far, as it is independent of any particular particle properties; so it has a universal value.

The factor 1 on the right side is not satisfying at the first glance as the measured spin corresponds to a factor of ½. It can, however, not be a surprise. Eq. (2.11) would be the angular momentum of the configuration of two objects, which orbit each other and carry half of the classical mass of an electron each. The configuration of the basic particle model is, however, different in the way that both objects (Basic Particles) do not have any classical mass.

In spite of this the lack of a conventional mass, the orbiting basic particles do have an inertial behaviour. The path on which they can move is destined by the field of the other partner. There are directions which a Basic Particle can follow without the effect of any force, and there are other directions, where a force, corresponding to the inertial mass of the entire configuration, is effective.

So the average angular momentum will be a bit less than $1 * \hbar$.

A factor of ½ as an average is possible, but it has still to be proven quantitatively.

2.4 The Spatial Quantization of the Spin

In the Stern-Gerlach experiment an atomic beam of spin 1/2 was split into 2 beams by an inhomogeneous magnetic field. From this observation it was concluded that the magnetic moment can only have 2 orientations in space and that therefore only 2 orientations of the particle's spin are possible.

If a particle flies towards the magnet, it can have arbitrary orientations is space. The magnetic force depends on the co-sine of the angle between its rotational axis and the direction of the magnetic field. Therefore it is classically to be expected that the distribution of the deflection angles has some kind of a flat shape. However, it was found that the distribution was peaked at two angles, which caused the assumption of 2 possible spin orientations.

An elementary particle built by two basic particles does *not* behave in this way. The magnetic force will depend on the co-sine as classically expected. However, from the Basic Particle Model it follows that also the inertial mass depends on the direction of the attacking force. The dependency of the magnetic force and the inertial force from the angle are correlated to each other. As a consequence the deflection distribution of the particles is suppressed in forward direction.

On the other hand, every force acting on the constituents of the electron with an axial component will cause the electron to perform a precession motion, as it behaves as a gyro.

The simultaneous action of both effects can at least to a certain extend explain the deviation of the Stern-Gerlach result from the classical expectation.

3 The "Zitterbewegung" and the Experimental Situation

The results for the electron presented above conform - together with the other properties of the model - to the parameters resulting from the Dirac equation of the electron. Historically Erwin Schrödinger has evaluated the Dirac equation, and he called the circulation within the electron (in German) "Zitterbewegung" (zbw).

This evaluation is causing headaches to the physicists since more than 70 years:

1. According to the Dirac equation the electron oscillates with the speed of light c. On the other hand the electron has a mass. By Special Relativity an object with mass can never move at the speed of light

2. A single object which moves freely in space can never oscillate, because this would mean a permanent violation of the momentum law.

In the view of the Basic Particle Model these discrepancies disappear:

1. Not the electron as a whole is oscillating but its constituents, the Basic Particles. These do not have any mass and can therefore move at the speed of light
2. As there are two constituents, there is no violation of the momentum law if these orbit each other.

However, there is a seeming discrepancy to the results of the experimental data of the electron: The experiments seem to indicate that the electron has no further constituents and has a size several orders of magnitude smaller than the value given above. - This discrepancy vanishes if the experiments are evaluated in the view of the Basic Particle model for the following reason:

A. To investigate whether the electron is built by several constituents, it was bombarded by other particles (e.g. protons) at a very high energy. The electron was not decomposed, so it was concluded that it does not have further constituents. However, in the view of the Basic Particle Model the constituents of the electron do not have a mass on their own. So, if one of the constituents is accelerated to the speed of light *c* which is the maximum possible, then the other constituent can follow without any delay. There is not even force acting on that constituent. So an electron can never break up.

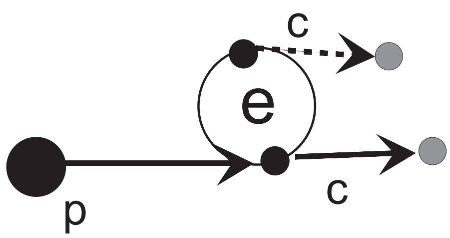


Figure 3.1: Experiment to break up an electron

B. The investigation of the size of the electron is done in the way, that the electron is scattered at e.g. a proton and the angular distribution is investigated. If the Basic Particle Model is assumed for the electron, then only one of the constituents will perform the scattering. Such experiments are performed with highly relativistic electrons. Due to the time dilation the constituents of the electron will move on a considerably stretched helix. One of the constituents will pass the proton as a normal, point sized, particle. The other particle will only indirectly participate in this scattering process in the way, that it causes the inertial behaviour of the whole electron. So the scattering will be the same as for a particle with a point like size but the mass of the electron. - From this result it is conventionally concluded that the electron (as every lepton) is point sized.

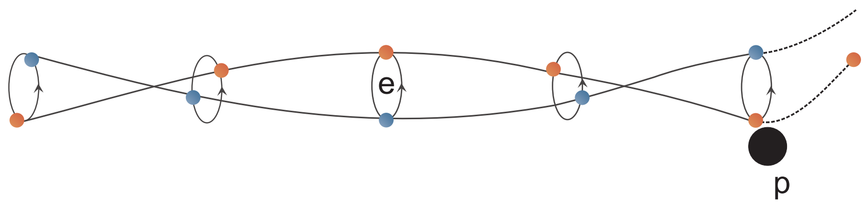


Figure 3.2: Experiment to determine the size of an electron

From the considerations above it should be obvious that the Basic Particle Model of the electron does not contradict the experimental results.

4 Summary

The "Basic Particle Model" provides a model for the understanding of the electron (as well as the other leptons and also for the quarks), which is based on classical physics and conforms to the experiments. And this model provides the origin of relativity on a 'mechanistic' basis.

NOTE:
The concept of the "Basic Particle Model" of matter was presented initially at the Spring Conference of the German Physical Society (Deutsche Physikalische Gesellschaft) on 24 March 2000 in Dresden by Albrecht Giese.

Comments are welcome to cc@ag-physics.de.

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