

# Electromagnetism at the Atomic Scale

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It is important to understand that just as Newton's laws were formulated for massive bodies, the laws of electromagnetism were formulated for situations involving large numbers of quantum strands of magnetic flux and large numbers of electrons in motion. When we scale down to atomic dimensions, both these conditions are broken. Thus we cannot assume that the laws of EM apply to the situation within atoms!

Realising this, we are empowered to seek a new set of laws which govern the behaviour of electromagnetism within the atom. The only requirement is that we can use them to derive the classical laws of electromagnetism for the situations in which they have been proven through application. In our unified theory, electrons and quarks are nothing but energy stored in a spherically symmetric electric field. Magnetism exists to give them the property of inertial mass. This theory not only explains the nature of inertia, but leads to a theory of relativity based on real causal effects.

The big change in concept is to regard the electric fields of individual elementary charged particles as coexisting in space and together forming a background against which the motion of an individual charge generates magnetic intensity  $\vec{H}_i = \vec{v}_i \wedge \vec{D}_i$ . Magnetic flux of flux density  $\vec{B} = \mu_0 \sum_i \vec{H}_i$  is then able to form subject to the limitation that magnetic flux is quantised. This gives us the basis of an electromagnetic theory of mass. Understanding how centrifugal force is generated, we find that the prime action of nature is one of doing work to charge the energy density of the magnetic fields which surround moving elementary charged particles and contain their kinetic energy. When electrons move in a co-ordinated manor, they generate magnetic fields on a macroscopic scale. We can derive the classical laws of electromagnetism from the basic properties needed to give elementary charged particles the property of mass.

At this point, we understand Electromagnetism at the very micro scale of individual elementary charged particles and at the macroscopic scale motors, generators and transformers. What we lack is an understanding of what happens at the atomic scale. We have discovered that:

- current loops generate magnetic fields
- the energy content of the magnetic field of a current loop is  $\frac{1}{2} I \Phi$
- current loops have a magnetic moment  $IA$

We need to add three more factors before we can begin to understand how Electromagnetism works at the atomic scale. They are:

- magnetic flux is quantised
- electron orbits are governed by orbital mechanics
- the equipartitioning of energy

While the Bohr model of the atom uses a crude knowledge of orbital systems equating centrifugal forces with electric force, we need to understand how the average potential and kinetic energies of the orbital system relate to each other. It then becomes a simple matter to solve the equations and show that the allowed orbits contain 1, 2, 3... quanta of magnetic flux.

We still need to understand how atoms interact with magnetic fields. The most important thing to understand is that the theory of motors, generators and transformers is all about changes in the quantity of magnetic flux in magnetic circuits. In general, the magnetic flux threading an orbit is constant! Only on the adsorption and emission of photons does it change.

When we place a current loop in a magnetic field of magnetic intensity  $\vec{H}_0$ , the integral  $\int \vec{H}_0 dA$  over the area of the current loop results in a change ( $\pm$ ) in the flux threading the loop. The action of nature is to try to increase the flux threading the loop. This in turn generates an emf opposing the current in the current loop and an additional voltage must be applied to maintain the current. The voltage driving the current does work, half of which goes to increasing the energy content of the magnetic field and half to doing mechanical work moving the current loop. This is the basic motor action. In an atom, there can be no change in the flux threading the orbit, so the motor action as we understand it cannot take place.

What does happen is an interaction between the orbiting electron and the whole of the magnetic field and when we perform the integrals, we arrive at the deceptively simple, but incorrectly named,  $Bev$  force  $\vec{F} = \mu_0 q \vec{v} \wedge \vec{H}$  of a magnetic field on a moving charge. This force affects the orbit changing both its radius and orbital frequency. Thus the current in the orbital current loop changes while the flux threading it remains constant. This has a most dramatic effect.

The motor action of a current loop in a magnetic field exists because nature tries to increase the energy content of the magnetic field. In the atom, the reverse happens and nature changes the energy content of the orbital system. For parallel alignment, the energy increases becoming less negative with the result the energy in the magnetic field decreases. For anti-parallel alignment, the energy of the system decreases becoming more negative while the energy in the magnetic field increases. The result is that the orbit shows no preference and will align either way.

We have only described the effects in this section. A full analysis is carried out in Quantum Theory within the Hydrogen Atom section.