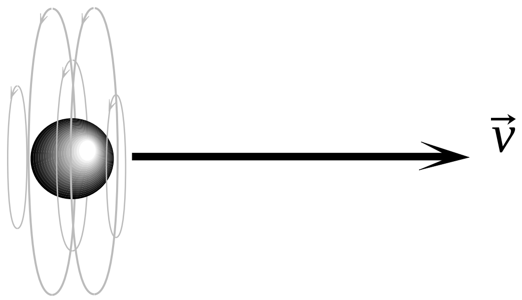
Electromagnetic mass

The discovery of the electron by JJ Thompson led to a frenzy of speculation about the nature of matter. Some, including JJ himself, thought that everything could be explained by electromagnetism. It took some time before Lorentz developed the theory of electromagnetic mass.

According to the laws of electromagnetism a moving electron should generate a magnetic field.



The realization that electrons are very small meant that the magnetic field could contain a significant amount of energy and possibly even its kinetic energy $E = \frac{1}{2} m v^2$. Lorentz postulated that the electron possessed two types of kinetic energy, one due to its mass and one due to its electromagnetic properties. He was then able to prove that the one due to its mass was zero and that the whole of its kinetic energy was stored in its magnetic field. This allowed Lorentz to calculate the radius a of the electron in terms of its charge e, mass m and the permeability of space μ_0:

$$a = \frac{\mu_0 q^2}{6 \pi m} = 1.897 \times 10^{-15} \text{ metres}$$

Modern Physics prefers a value of 2.8179×10^{-15}, but a more logical analysis might be to equate Einstein's $E = m c^2$ with the enegy stored in the electric field to give 1.409×10^{-15}. The electron has anti-matter equivalent called a positron. If an electron and a positron meet, then they annihilate each other giving off their energy as two gamma rays. This has made it possible to measure the energy and confirm Einstein's $E = m c^2$. We can make sense of both the Lorentz's electron radius and Einstein's $E = m c^2$ if we take into account the potential energy that the electron and positron have due to the distance between them. We can then work backwards and calculate the distance between them at the moment of annihilation. This gives a separation between their centres of 3 times the Lorentz radius.

In itself, the theory is unremarkable, but its triumph came from the fact that it was able to explain why electrons moving at near light speed showed an increase in mass. However, the rising prominence of Einstein led to Lorentz's work being lost in the mists of time even before the discovery of the Neutron put an end to the theory of electromagnetic mass because the neutron had no electric charge. The development of a new theory in 1964 which said the protons and neutrons both consisted of three quarks which had an electric charge should have led to revival of Lorentz's theory.

The original attempts to develop the theory to account for the mass increase were made by Lorentz and Abraham. Both depended on the Lorentz contraction which was derived quite simply from Maxwell's laws, but both made a fundamental mistake of not understanding how the contraction worked. They thought that the Lorentz contraction would affect the energy stored in the electric field. Our unified theory corrects this error proving that it remains constant. Only the magnetic field is affected.

Once it is understood that the energy content of the electrons's electric field remains constant, the mass increase can be derived quite simply for acceleration in the direction of its motion. Centrifugal force remains more of a mystery and the classical laws of electromagnetism are unable to account for it. The key to understanding centrifugal force lies in the nature of the basic interaction between a moving electron and a magnetic field. Centripetal (towards the centre) acceleration cause a change in direction resulting a rotation of the magnetic field. When we realise that energy moves between the magnetic field and the surface of the electron parallel to its electric field it becomes obvious that this rotation requires energy to move both to and from the electron generating a net centrifugal force resisting the centripital acceleration.

While this discovery is central to our unified theory, it is very mathematical. We do not need to know the details to continue with our derivation of the laws of electromagnetism. The analysis of the mass increase is more properly dealt with in our Physicist level Relativity sections.