Magnetism

Einstein's paper of 1905 was called The Electrodynamics Of Moving Bodies. His derivation of the Lorentz transforms is only a small part of the paper. He starts with a criticism of the laws of electromagnetism in which he complains that two theories are required to describe the interaction between a magnet and a circuit, one theory is used when a wire is moved past a magnet, but a different theory is required when the magnet is moved past the wire. It must be said that modern teaching in engineering departments does not make this distinction. Maxwell, however regarded the magnetic field as being stationary in the æther, so that in the case of a moving magnet, there is a continuous process of the rear of the field decaying as the front grows in strength.

Einstein's solution to this problem was drastic. He denied the existence of the magnetic field as a physical entity and reduced it to the rank of an artefact of observation[4iii]. For an engineer building power station generators, this would have been an obvious nonsense, but in the rarefied atmosphere of a university mathematics department pursuing theoretical physics with a sense of distrust in experimental physics, it was not such a bad idea. We might take as an example the explanation of why a wire carrying an electric current might exert a force on a similar parallel wire. This is to be found in standard texts and is regularly taught at university.

The electric current in the wire consists of moving electrons. It is claimed that because they are in motion, the whole set appears contracted in the direction of motion. The electrons are consequently closer together and the wire is said to carry a net negative charge. The positive lattice ions in the other wire are supposedly attracted by this net negative charge and hence the wires are attracted towards each other. That is what is taught. It is of course nonsense. The drift speed of electrons in a wire carrying an electric current is measured in millimetres per hour, not exactly close to the speed of light! The extra electrons would have to come from somewhere: perhaps heaven! We might alternatively argue that the electric fields of the individual moving electrons are contracted and so more intense, but this encounters two problems, first that the average field would be unaffected because the total electric flux would remain constant, secondly even if the averaging process did not take place, it is based on the false assumption that D and E are basically the same thing. The electric flux density D is not responsible for the electric force. The force results from the change in electric potential with change of position. The nature of the contraction does not affect the component of $\vec{E} = \nabla\phi$ perpendicular to the current.

In the SI system of units, the descriptors D and E of the electric field have different dimensions as do B and H of the magnetic field. Magnetic fields are generated as a result of the motion of elementary charged particles through the background. $\vec{H} = \sum_i \vec{v}_i \wedge \vec{D}_i$, the sum being taken over all elementary charged particles. It is wrong to think of $\vec{H}$ as a physical entity. The physical entities are the moving electric fields of the elementary charged particles. $\vec{H}$ is just a mathematical artefact describing the sum of the effects. In response to $\vec{H}$ a magnetic field of flux density $\vec{B} = \mu_0 \vec{H}$ is formed. The magnetic flux is a physical entity and contrary to Maxwell's understanding, its locus is that of the electric circuit or ferromagnetic material which generates it. In taking the summation $\sum_i \vec{v}_i \wedge \vec{D}_i$ the elementary charged particles can be divided into sets whose net contribution is zero. For those in the electric circuit, conduction band electrons can be paired with lattice particles and the absolute velocities then subtract to give the velocity of the conduction band electrons relative to the circuit or magnet. The same applies to a magnet, pairing orbital electrons and lattice ions.

A sophisticated electromagnetic theory can be deduced on the basis that each electron contributes to the energy density of the magnetic field according to its contribution $\vec{H}_i = \vec{v}_i \wedge \vec{D}_i$ to the generation of the magnetic field with energy flowing within its electric field parallel to $\vec{D}_i$. This analysis leads to a rigorous derivation of the laws of induction in which they are seen to be a consequence of the nature of inertia.

The irony is that Maxwell is shown to be wrong. Magnetic flux does not have its seat in the æther, it is a physical entity in its own right with definite locus and velocity through the stationary system. That is not to say that Maxwell's equations are wrong: the mathematical analysis yields the same equations whether we consider the magnetic flux to be stationary or moving. There are two ways of looking at a wave, one is to look at the water level at a point and see it going up and down, the other is to see the wave moving over the water surface. Whichever view one might prefer, the mathematics of wave motion remains the same.