

# Electric and Magnetic fields

HOME: [The Physics of Bruce Harvey](#)

## Units and Dimensions

We use SI units in their microscopic form. We extend the traditional dimensional analysis of Mass, Length and Time to include electric Charge. Every effort is made to keep equations dimensionally consistent.

The electric and magnetic field descriptors have dimensions:

$$D \rightarrow [C] [L]^{-2} \quad E \rightarrow [M] [L] [T]^{-2} [C]^{-1} \quad H \rightarrow [L]^{-1} [T]^{-1} [C] \quad B \rightarrow [M] [L]^{-1} [T]^{-1} [C]^{-1}$$

In some of the older systems of units based on the three dimensions of Mass, Length and Time;  $D$  and  $E$  have the same dimensions as do  $B$  and  $H$ . Understanding that they are physically different properties of their respective fields is essential to understanding the nature of those fields.

## Electric fields

Classical physics defines the electric field strength  $E$  as the force per unit charge on a vanishingly small test charge. This definition corresponds to a concept of the electric field as singular. We believe this to be the biggest single mistake in Physics.

The generation of a magnetic field by an electric current is described in Classical Physics by the empirical law of Biot-Savart. We have derived this law from the assumption that:

- 1 That there exists a background against which the electromagnetic interactions take place.
- 2 That an elementary charged particle of charge  $q_i$  and electric field  $\vec{D}_i = \frac{q_i \hat{r}_i}{4 \pi r_i^2}$  moving with velocity  $\vec{v}_i$  relative to the background has an action:

$$\vec{H}_i = \vec{v}_i \wedge \vec{D}_i$$

- 3 That a magnetic field with descriptors  $\vec{H}$ ,  $\vec{B}$  forms as a result of the sum of these actions:

$$\vec{H} = \sum_i \vec{H}_i \quad : \quad \vec{B} = \mu_0 \vec{H}$$

We therefore believe that the law of Biot-Savart reveals Nature's fundamental process of generating a magnetic field. It implies that each conduction band electron has an individual electric field of flux density  $\vec{D}_i$  and that its motion with velocity  $\vec{v}_i$  relative to the circuit has an action  $\vec{v}_i \wedge \vec{D}_i$  and that these actions sum to give the magnetic intensity  $\vec{H}$ . For this to happen, the electric flux of each charge must coexist in space with the electric flux of all other charges.

The electric field of an electron consists of a quantity  $\Psi_e$  of electric flux with a flux density  $\vec{D}_i$ . This is its substance and it extends throughout space. We accept Maxwell's assertion that the electric flux of electromagnetic radiation terminates in displacement charge, but extend this concept to include the electric fields of all elementary charged particles. That is to say that the charge of an elementary particle is nothing but the displacement charge at the inner end of the flux which forms its surface.

We assert that the force which one elementary charged particle exerts on another is due to a local action between the particle subject to the force and the extended electric flux of the other, in which it sits. The exact

process by which this happens remains a mystery. The simple concept of a polarisation of the vacuum in R3 is inadequate and it seems likely that a fourth non-extended dimension is required. Mathematically, we can express this action as a potential  $\phi_i$ . It makes good sense to regard the potential as a fundamental property of the electric field and to define the electric field strength  $\vec{E}_i = \nabla\phi_i$  as the gradient of that potential.

The classical electric field strength and flux density then become the mathematical artefacts:

$$\vec{E} = \sum_i \nabla\phi_i \quad \vec{D} = \sum_i \vec{D}_i$$

Understanding that the electric field is not singular and that the electric fields of all elementary charged particles exist separately in space moving through each other is essential to our unified theory. The descriptors  $\vec{D}$  and  $\vec{E}$  of Classical Physics are to be regarded as mathematical artefacts. The potential and flux density of the electric field of each elementary charged particle are real properties of its electric flux which is the real physical entity.

## Magnetic fields

Like electric flux, magnetic flux is a real physical entity. Electric and magnetic fields are entirely complementary. Attempts to unify the electric and magnetic forces into a single force are in our opinion futile. They come as a pair with complementary properties which are essential to the existence of elementary particles and matter.

The elementary particles are formed from electric flux, but if that was all, then all of the positive and negative charged particles would rush towards each other with infinite acceleration. Magnetic flux exists to give them the property of inertia.

The action of an electric current in a circuit generates a magnetic field. The simplest equation describing this action is:

$$\vec{H} = \sum_i \vec{v}_i \wedge \vec{D}_i$$

We see that magnetic field intensity  $\vec{H}$  is in fact a property of the motion of electric fields. This is because of the complementary/unified nature of electric and magnetic fields. Modern physics recognises this relationship, but then fails to realise that magnetic flux of quantity  $\Phi$ , length and flux density  $\vec{B}$  is a real physical entity.

The work of Oersted was not helpful. He investigated the properties of the behaviour of engineered artefacts. Magnetic poles are man made objects and the fact that they appear to exert forces on each other in the same way as electrically charged objects is misleading.

The primary purpose in nature of magnetic fields is to surround moving elementary charged particles and contain their potential energy. When elementary charged particles move in a co-ordinated way, they generate an extended magnetic field. This is a secondary function of nature. If we are to understand how nature works, then we must start with the primary function and extend our understanding to explain the secondary action.

The primary interaction between a charged particle and its surrounding magnetic field is one of energy exchange. Acceleration increases its speed and requires an increase in the energy content of its magnetic field. This requires a force to act through a distance doing work. This is the fundamental action of slowing the acceleration of a particle. It has a reverse action in that the charge is able to do work against a retarding force which reduces its speed and the energy content of its magnetic field.

The forces between magnets and the forces magnetic fields exert on electrons and conductors have to be

understood in this context. The key to understanding magnetic forces is to expand the expression for the energy density of a magnetic field:

$$Q_m = \frac{1}{2} \vec{B} \cdot \vec{H} \quad \Rightarrow \quad Q_m = \frac{1}{2} \vec{B} \cdot \sum_i \vec{v}_i \wedge \vec{D}_i \quad \Rightarrow \quad Q_m = \frac{1}{2} \sum_i \vec{B} \cdot (\vec{v}_i \wedge \vec{D}_i)$$

We then see that the motion of every charged particle contributes to the energy density of the magnetic field. The force on an electron results from the need to do work (or have work done to it) as its contribution to the energy density changes. The action of generating a force  $\vec{F} = e \vec{v} \wedge \vec{B}$  relates to the relationship between the electron and the loops of flux through which it is passing. It involves some difficult volume integrals which have to have be done by dividing space into flux tubes.

We find that we can explain both the generation of inertial forces and magnetic forces.

$$\text{Div } \vec{B} = 0$$

For magnetic fields which result from the motion of elementary charged particles:

$$\vec{D}_i = \frac{q_i \hat{r}_i}{4 \pi r_i^2}, \quad \vec{H}_i = \vec{v}_i \wedge \vec{D}_i \quad \text{and} \quad \vec{B} = \mu_0 \vec{H}$$

It follows that

$$\text{Div } \vec{H}_i = \frac{q_i}{4 \pi} \text{Div} \left( \frac{\vec{v}_i \wedge \hat{r}_i}{r_i^2} \right)$$

It is a simple matter for those skilled in vector calculus to prove that  $\text{Div} \left( \frac{\vec{v}_i \wedge \hat{r}_i}{r_i^2} \right) = 0$ . Dropping the subscripts, we impose Cartesian co-ordinates such that  $\vec{v}_i$  lies in the x axis.

$$\vec{v} = \begin{pmatrix} v \\ 0 \\ 0 \end{pmatrix}, \quad \hat{r} = \begin{pmatrix} x \\ y \\ z \end{pmatrix} \quad \text{then} \quad \frac{\vec{v} \wedge \hat{r}}{r^2} = \frac{\vec{v} \wedge \vec{r}}{r^3} = \frac{1}{r^3} \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v & 0 & 0 \\ x & y & z \end{vmatrix} = \frac{1}{r^3} \begin{pmatrix} 0 \\ -v z \\ v y \end{pmatrix}$$

$$\text{Div} \left( \frac{\vec{v}_i \wedge \hat{r}_i}{r_i^2} \right) = \frac{d}{dy} \frac{-v z}{(x^2 + y^2 + z^2)^{\frac{3}{2}}} + \frac{d}{dz} \frac{v y}{(x^2 + y^2 + z^2)^{\frac{3}{2}}} = 0$$

Thus  $\text{Div } \vec{H}_i = 0$  and since  $\vec{H} = \sum_i \vec{H}_i$ ,  $\text{Div } \vec{H} = 0$  and where  $\vec{B} = \mu_0 \vec{H}$  it follows that  $\text{Div } \vec{B} = 0$ . This is fortunate because magnetic flux is real physical stuff consisting of quantum strands which form closed loops requiring that  $\text{Div } \vec{B} = 0$ .

$$\text{Is } \vec{B} = \mu_0 \vec{H} ?$$

It is generally accepted that  $\vec{B} = \mu_0 \vec{H}$  and this is indeed so for magnetic fields which result from the motion of elementary charged particles. But magnetic fields are half the substance of radio waves and photons. When we try to account for the geometry of their magnetic flux so as to maintain the requirement that  $\text{Div } \vec{B} = 0$ , we find examples where the the flux links between consecutive half phases or where one side of the flux loop lags behind the other in phase. Since  $\vec{D}$  and  $\vec{H}$  are necessarily perpendicular to each other and the velocity, we would expect  $\vec{B}$  to be perpendicular to the velocity. As this condition is violated, then we must question the relationship  $\vec{B} = \mu_0 \vec{H}$ .

In our unified theory,  $\mu_0$  is a property of the magnetic field. We regard it as a mistake to assert that it is a property of space. Space has no substance and therefore no properties. Electric and magnetic fields exist in space and they have the properties of permittivity and permeability. Our unified theory states that these

properties relate to their ability to contain energy. An essential part of our unified theory is the assertion that the magnetic intensity is the sum of the actions of the moving electric flux of all the individual elementary charged particles coexisting in space. We assert that the energy density of a magnetic field generated by their motion is given by:

$$Q_m = \frac{1}{2} \vec{B} \cdot \vec{H} = \frac{1}{2} \vec{B} \cdot \sum_i \vec{H}_i$$

Thus, if  $\mu_0$  describes a property of the magnetic field relating to its ability to contain energy, then we cannot separate that property from the above equation. The property depends on the angle between the magnetic flux density vector  $\vec{B}$  and the magnetic intensity vector  $\vec{H}$ . For magnetic fields generated by the motion of elementary charged particles, they are parallel and  $\vec{B} = \mu_0 \vec{H}$ . But the magnetic flux of radio waves and photons is generated through the motion of their electric flux which is itself generated by the motion of the magnetic flux. Its geometry is not constrained such that it is everywhere perpendicular to its velocity and  $\vec{B}$  and  $\vec{H}$  are not necessarily parallel.

We assert that the more general relationship is:

$$\vec{B} \cdot \hat{h} = \mu_0 H \quad \Rightarrow \quad \vec{B} = \mu_0 \vec{H} \text{ when } \vec{B} \parallel \vec{H}$$

Where  $\hat{h}$  is the unit vector parallel to  $\vec{H}$ . This allows the flux density vector to have a component  $\vec{B}_{\perp h}$  perpendicular to  $\vec{H}$  as well as a component  $\vec{B}_{\parallel h}$  parallel to  $\vec{H}$ .

We have dealt with this in more detail in the section on Circular Polarisation.

## The background

The equation  $\vec{H} = \sum_i \vec{v}_i \wedge \vec{D}_i$  contains the term  $\vec{v}_i$  which was stated to be the velocity of an individual conduction band electron relative to the circuit. We know from the study of coronal discharge phenomena that free moving charged particles can generate magnetic fields. Velocity is always measured relative to something; but free moving charges have no local reference frame against which we can measure their velocity. Maxwell's treatise assumes the presence of an æther against which it is natural to measure velocity. Despite great efforts, no satisfactory æther theory was ever developed.

It seems most likely to the author that the coexisting electric fields of all elementary charged particles forms a background against which the motion of an individual charged particle generates a magnetic field. Two questions must be answered. Do we believe that the strength of the magnetic interaction is proportional to the number of elementary charged particles whose electric fields form the background. Do we believe that their influence is moderated by a distance law. The author now believes that the strength of the interaction is independent of the number of charges and that their influence is moderated by their electric potential  $|\phi_i|$ .

This gives us a way of calculating the velocity of the background relative to a frame of reference:

$$\vec{s} = \frac{\sum_i \vec{v}_i |\phi_i|}{\sum_i |\phi_i|}; \quad \vec{s} \equiv \frac{\sum_i \vec{v}_i \left| \frac{M_i}{r_i} \right|}{\sum_i \left| \frac{M_i}{r_i} \right|}$$

and that for all practical purposes we can perform the summations using the masses of planets, stars and galaxies. Since none of this data is available, we are limited to a guessing game based on what we think we know about the distribution of mass in the galaxy and the universe. Our best guess is that the background in our region of space moves linearly with the Galaxy and rotates with it, but at a slower angular velocity.

## Moving magnetic fields

There are some things which are undetectable. One of these is the emf generated along the wings of an

aircraft as it flies through the earth's magnetic field. We cannot detect it because an equal emf is generated in the wires we use to connect the voltmeter. We meet a similar problem if we try to measure the velocity of the laboratory through the background using a magnetic field.

Matter is full of magnetic fields. Every moving elementary charged particle has its own magnetic field generated by its motion through the background. All of the actions of these magnetic fields moving through the background generate emf. However, these emfs result in the Lorentz contraction, increase in mass and slowing of time dependent processes rendering them undetectable. Moving magnetic fields are only able to generate independent electric fields when they move at the speed of light in the form of photons or radio waves. The process by which an emf is generated in a circuit when the magnetic flux threading it changes is a far more complicated thing involving the summation of the individual interactions between the conduction band electrons and the magnetic field. It just so happens that when these summations are performed, the result corresponds to the cutting of the circuit by the mathematical artefact  $\mu_0 \vec{H}$ .

## Quantisation of flux

Maxwell describes with delight how Faraday envisaged the concept of tubes of flux. Unfortunately, the size of the units for magnetic flux and electric charge were far too big to allow a correct conceptualization. Since Maxwell's time, we have discovered the electron and the quantum fluxoid and gone on to hypothesize the existence of the U and D quarks.

In hind sight, Faraday's tubes of flux are a physical reality, the only question being the size of the electric fluxoid. The experiment of Deaver and Fairfax with short lengths of fuse wire confirmed that magnetic flux is quantised. The quanta of magnetic flux is  $2.0678506 \times 10^{-15}$ . This may seem very small, but even inside the most powerful magnets, the cross section of a quantum fluxoid contains tens of thousands of atoms.

The author favours a value of one sixth of the charge on the electron for the quanta of electric flux which would readily explain the charges on the D and U quarks and the electron. This allows a model of the photon as consisting of a number of phases each consisting of a magnetic quantum fluxoid and an electric quantum fluxoid.

The author does not see Plank's constant  $h$  as a fundamental property of nature, but a derived artefact dependent on the quantisation of electric and magnetic flux. Because both atomic structure and photon structure depend on the interaction of quantised electric and magnetic flux, both yield Plank's constant  $h$  in the solution of their energy levels.

There are still one or two problems to be solved before we fully understand the behaviour of the quantised flux in relation to the extended magnetic field. Saturation of a magnetic field in a ferromagnetic material corresponds to a fluxoid cross section of thousands of atoms. Nor are we sure how to scale down our understanding of mutual inductance and the force between circuits so that we may understand the fine structure and hyperfine structure of spectral lines.