Secondary field theory

Abstract

The field diagram for an electromagnetic wave shows that electric and magnetic field vectors violate Gauss's laws. This is corrected and wave motion is explained by introducing a dipole field geometry for the photon. The dual wave-particle nature of photons is also accounted for by means of classical fields and vector addition.

1.0 Introduction

A highly publicized goal of field theory is to unite the gravitational and electromagnetic fields. Little or no progress has been achieved in this endeavor. However, a more traditional purpose of field theory was to express the wave and particle properties of matter using only fields. The resulting model has been referred to facetiously as a "wavicle". Einstein, Schroedinger, and de Broglie all discussed different aspects of this problem. When a satisfactory solution could not be found the Copenhagen version of quantum theory was introduced. It concluded that photons and other particles include both wave and particle aspects simultaneously, and that only the mathematics are relevant when determining the results of experiments.

2.0 The mathematics of classical electromagnetic wave theory

2.1 Field transformation

Two of Maxwell's equations describe how electric and magnetic fields transform continuously in time.

$$\nabla \times \vec{E} = -\partial \vec{B}/\partial t \qquad 1) \qquad\qquad \nabla \times \vec{B} = \mu_o \vec{J} + \mu_o \varepsilon_o \partial \vec{E}/\partial t \qquad 2)$$

We can easily verify them in the laboratory using a permanent magnet and a coil of wire. The first equation describes how a current is generated when a magnet moves past a coil of wire (or vice versa). Equation 2) tells us that a magnetic field forms if a current flows through the wire causing a varying electric field. When expressed in terms of charges and fields the two pictures are symmetrical. Magnetic field can be generated by moving electrical fields (currents) and electric fields can be generated by moving magnetic fields.

It is also possible for field transformation to occur at the speed of light as an electro-magnetic wave. The electric and magnetic fields transform in the same manner and vectors obey the right hand rule in both cases. However, the transformations that occur in a wave appear to be very different from those produced by a magnet and coil of wire. Although the above description by fields is symmetrical, due to the displacement current $\vec{J}$, equations 1) and 2) are not symmetrical. Because $\vec{J}$ does not exist as a real current (movement of charge) it does not appear in the field diagram in figure 1. It is an imaginary quantity that is proportional to the change of an electric field and whose primary purpose is to justify the existence of electromagnetic waves. In other words, it provides a mechanism for producing continuous sinusoidal magnetic fields.

2.2 Field geometry

The remaining two Maxwell's equations, referred to as Gauss's laws, define how fields are configured, which we shall refer to here as the geometry of the fields.

$$\nabla \cdot \vec{B} = 0 \qquad 3) \qquad\qquad \nabla \cdot \vec{E} = \rho/\varepsilon_o \qquad 4)$$

Equation 3) states that magnetic field lines are found in the form of closed loops and equation 4) indicates that electric fields radiate outwardly from points. However, in figure 1 electric and magnetic fields are shown as open-ended vectors which do not conform to either equation. Why are the lines of field in an electromagnetic wave open-ended? What causes them to originate and what determines their length (intensity)? Finally, why don't the fields in an electromagnetic wave conform to Maxwell's laws 3) and 4) for field geometry?

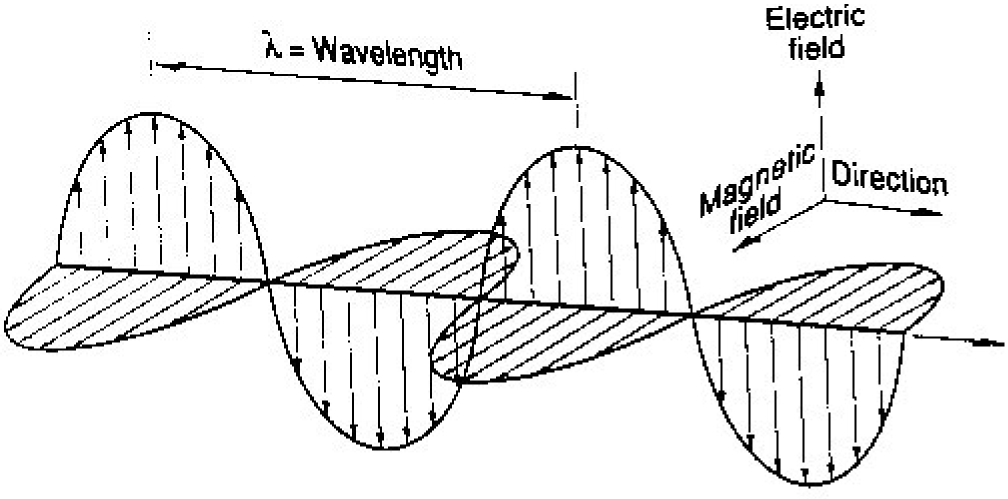

Figure 1. The electromagnetic wave

The electromagnetic wave is unique in nature. It is emitted as a wave, propagates as a wave, and is detected as a wave without changing its form. Every other object in nature must be disturbed in some way, perhaps by bouncing a particle off of it, in order to be observed. Why is it then that the electromagnetic wave is always the same, even in empty space when no one is looking? Are our perceptions of a wave and the wave one and the same? Experience tells us that our senses give us an incomplete understanding of natural phenomena. Quantum mechanics expresses this formally with the uncertainty principle, which suggests that particles in isolation cannot be detected. Perhaps fields also need to be disturbed to be seen. Although the electric and magnetic fields of an electromagnetic wave appear to disturb each other symmetrically and in a reversible manner field component diagrams do not give any hints how this happens. What changes when fields vary intensity and where do electric fields disappear to when they change polarity? Let us analyze the properties of fields more closely.

3.0 Quantum theory

3.1 The classical photon

Although classical electromagnetism theorizes the existence of pure fields by using a test charge, test charges are fictional. Let us assume instead that a pure field in isolation cannot be detected so that one field must be disturbed by another field to verify its existence. Then there would be no way of observing an independent field such as the electromagnetic wave. However, because the electromagnetic wave includes two components, magnetic and electric fields, we may speculate that one of them causes the other to appear. We know that electromagnetic waves are generated by a charge oscillating back and forth on an antenna. From equation 2) we know that moving charges cause a magnetic field to be generated. Therefore a magnetic field must be the first field to be created by an emission process.

The field diagram of the electromagnetic wave does not satisfy Maxwell's equations 3) and 4) denoting field geometry. We seek to describe the classical electromagnetic wave in a way that accomplishes this and at the same time provides for its physical interpretation in a way that is compatible with the uncertainty principle. These requirements are fulfilled if we conceive of the photon as a magnetic dipole in rectilinear motion whose axis is aligned with its path. The completed interaction picture of an electromagnetic wave frozen in time is shown in Figure 2, where shaded ellipses represent negative charges and closed lines represent $\vec{B}$ field. In other words, a photon is conceived of as having a constant $\vec{B}$ field consisting of a series of closed loops to infinity. Transverse wave motion results when the static magnetic potential moves past positive or negative charge centers. Force vectors are given by the right hand rule together with the Lorentz force equation $\vec{F} = q/c\left(\vec{v} \times \vec{B}\right)$, where $\vec{v} = \vec{c}$. This represents the simplest known disturbance in nature because even though electrons are placed in motion no energy is exchanged. We know this to be true because experiments show that a static magnetic field does not contribute to the energy of a charge in uniform relative motion.

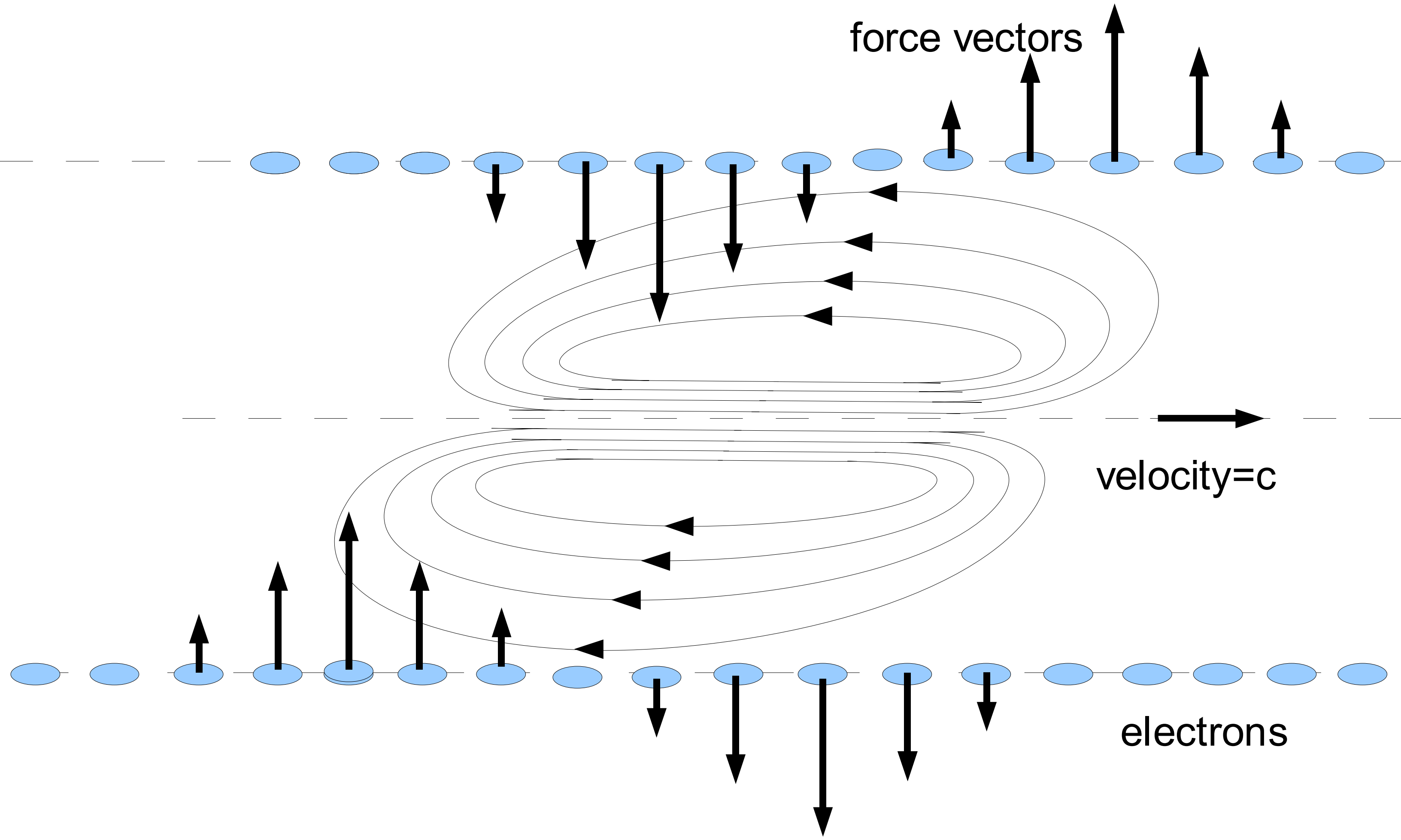

Figure 2. The intersection of magnetic and electric fields give the appearances of wave behavior.

We have described wave motion using equations 1), 3), and 4). Equation 2) is unnecessary because the changing electric fields in figure 2 do not generate a magnetic field. Equation 1) describes a static $\vec{B}$ field that varies continuously $-\partial \vec{B}/\partial t$ due to its motion thereby generating an electric field $\nabla \times \vec{E}$. In contrast to figure 1 the requirement of closed field lines by equation 3) is now upheld. The disappearances and/or reversals of $\vec{E}$ field which occur during wave motion are automatically determined by the vector product. The absence of magnetic waves in free space means that fictitious "displacement currents" are unnecessary and equation 2) may be made symmetrical to equation 1) by eliminating $\vec{J}$ thereby yielding the equation $\nabla \times \vec{B} = \mu_o \varepsilon_o \partial \vec{E} / \partial t$. The "poles" of the magnetic dipoles do not influence each other because that would require forces that propagate faster than the speed of light. We see therefore that the fields must be separate and have a causal relationship between them in order for all of Maxwell's equations to be satisfied.

3.2 Duality and complementarity

Many simplifications may now be implemented, the foremost being an elimination of photons as field singularities and the introduction of magnetic field sources to balance the existence of electric field sources. This allows much of quantum theory to be interpreted using classical field theory. The dual wave-particle nature of photons is explained by means of field geometry and vector addition. Diffuse external fields cause wave behavior while the concentrated fields at the photon's core cause particle behavior. The uncertainty relations may be derived in terms of the spatial extension of the photon, or the volume of space-time that it occupies. Perfect localization would only be possible if the photon were a singularity.

In quantum mechanics field energy is equated with photon density. This leads to the statistical implementation of the conservation laws in diffraction and interference phenomena. However, direct tests of these laws in individual interactions have confirmed their legitimacy to the highest levels of accuracy possible. If instead photons are conceived of as ordinary particles surrounded by a continuous field potentials as in figure 2, then photon fields can be made to disappear by superposing the field potentials of other photons. The photon will then reappear when its path diverges from the others. Therefore field intensity is unrelated to photon number and the conservation laws are upheld. If it is difficult to understand how photon fields can completely disappear one needs only think of the atom in which electric fields due to electrons and nucleus can be made to disappear completely. Field superposition allows detection events to be conceived of as the statistical superposition of classical fields rather than as the collapse of wave functions. Wave packets containing many photons may be divided by beam splitting mirrors into multiple wave packets each with field potential sufficient to cause electron excitation.