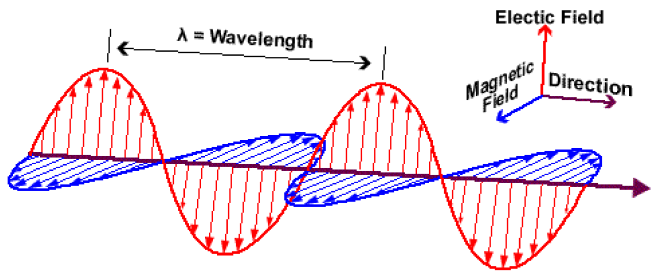

Figure 31: An electromagnetic wave consists of oscillating electric and magnetic fields, which are perpendicular to each other and also perpendicular to the direction of motion of the wave.

6 Particles and Fields

It is possible to discuss a more concrete quantity which is closely related to the wave-function. Here we enter the even more advanced subject of Field Theory. In this theory, every particle has a field associated with it. In the case of photons, we understand this field - it is the electromagnetic field. An electromagnetic wave consists of an oscillating electric and magnetic field perpendicular to each other and also perpendicular to the direction of the wave as shown in Fig. 31. For a photon, the wave motion of either the electric or magnetic field is related to the photon matter wave in such a way that the amplitude of the electric or magnetic field wave is large when the amplitude of the matter wave is large, (and small when the amplitude of the matter wave is small). This means that the amplitude of the electric or magnetic wave at any point, $\mathbf{x}$, at time, t, is closely related to the probability that the photon is at the point $\mathbf{x}$ at time t.[8] It turns out that all particles have such fields associated with them. For a wavepacket of electromagnetic radiation, the probability to find a photon at a particular position is proportional to the amplitude of the wave at that point.

We are familiar with electric and magnetic fields but not with the field associated with electrons, or other massive particles, simply because for a massless particle (e.g. a photon) the electric or magnetic field is only mildly attenuated - decreasing as the square of the distance from its source, whereas the field of a massive particle is very rapidly attenuated. For example, for an electron the field is heavily attenuated after a distance of 0.0025 nm. It is therefore possible to perform experiments on electric and magnetic fields in the laboratory (you probably carried out some such experiments at High School) but clearly impossible for fields associated with massive particles. Nevertheless each particle does have such a field associated with it and for a moving particle this field evolves in a wave-like motion with an amplitude that is closely related to the amplitude of the matter (de Broglie) wave.

[8]The precise relation between the electromagnetic field associated with a photon and the de Broglie wave is very complicated and can only explained using Quantum Field Theory. It is way outside the scope of this article.