A Classical Quantum Theory

Introduction

The Quantum Theory was developed to explain the structure of atomic spectra and the random nature of radioactive decay both of which seemed to contradict the principles of classical physics. The historical context is that towards the end of the nineteenth century Classical Physics seemed well developed. Everything was governed by exact physical laws and nature went about her business with the precision of a clock. Maxwell's laws explained almost everything and had enabled the technological revolution of electrical engineering. Then Thompson's discovery of the electron opened the way to Rutherford's revelation that atoms were not solid balls, but empty space inhabited by a positive nucleus and orbiting electrons. The discovery of radioactivity showed nature acting randomly breaking the neat laws of Newtonian determinism. The attempts of Lorentz to show that even mass was electromagnetic in nature had come to nothing. In 1905, Einstein reinterpreted the work of Lorentz and Poincaré in his theory of Special Relativity which gained wide acceptance some 11 years later with the publication of his theory of General Relativity.

In my earlier works, I have shown that the historical ordering of discoveries is a determining factor in the development of theories. By imagining a different history in which we take selected modern discoveries and tools back in time, we are able to take alternative routes of reasoning and develop alternative theories. Thus by taking the model of a nucleus consisting of protons and neutrons built of Up and Down quarks, and correct data on the variation of mass with speed of beta rays, it is possible to complete Lorentz's work on inertial mass. As the consequences of this are explored, we find that a "Lorentz Poincaré Relativity" would have prevailed over Einstein's Special Relativity. The two theories sharing the same equations, but having different physical interpretations.

One of the consequences of the adoption of Einstein's relativity was that it robbed magnetic fields of their substance. In classical physics, magnetic fields consist of magnetic flux which has an energy density and is very real. In Einstein's theory, observers in different states of motion observe different magnetic fields and this is explained by postulating that magnetic fields are an artefact of observation caused by the observer's motion relative to an electric field. Returning to a Lorentz Poincaré world in which magnetic fields are real opens the way for a classical explanation of atomic spectra. In addition to this we take back in time the discovery that magnetic flux behaves as if it is quantised.

The result is truly amazing.

Electron orbits

The nature of magnetic fields is profoundly affected by their geometry. Wind a solenoid to form an inductance and theory will accurately predict its inductance. Reduce the solenoid to a single turn of wire and its inductance becomes dependent on the diameter of the wire. Theoretical analysis only produces integrals which have no algebraic solution. When we look at Lorentz's theory of inertial mass, we find the electron surrounded by a magnetic field of incredible strength. The lines of force form circles about its line of motion and the magnetic flux moves with the electron. When we look at a solenoid, it is the combined action of the motions of the electrons within the wire that causes the magnetic field to form. The lines of flux are now stationary relative to the solenoid.

If we apply the principles of classical physics to the Rutherford model of a hydrogen atom, we are tempted to see the orbiting electron as forming a current loop and generating a magnetic field. Alternatively, we might look on the orbiting electron and apply Maxwell's laws concluding that it must be radiating vast amounts of energy in the form of electromagnetic radiation. The electron should spiral into the nucleus collapsing the atom!!!

The missing link is the quantization of magnetic flux. The moving electron is generating two distinct magnetic fields with different scales and different geometries. One very strong moving with the electron, surrounding it with the lines of flux forming circles about its direction of motion; the other sitting within the current loop formed by its orbit. Now classical physics gives us a way of calculating the strength of this magnetic field at its centre. In round figures, this is 12.5 T, which is about 5 times the magnitude of the strongest field we can create with magnets. But when we take into account the extremely small size of electrons orbit, we find that the flux in that area of a 12.5 T field is only 1.1×10^{-19} W compared with he quantum fluxoid's $\Phi_0 = 2.07 \times 10^{-15}$ W, there seems to be no match.

It is only when we take on the task of writing a computer program to compute an accurate numerical integration that tings suddenly start to make sense. We find that as we approach very close to the wire of a current loop, the magnetic field strength approaches $\frac{\mu_0 i r}{\pi x^2}$ where r is the radius of the loop and x the distance from the centre of the wire. Integrating from the centre of the loop towards the electron's orbit, we find that the quantum fluxoid will fit within the orbit leaving a narrow tunnel about twice the diameter which Lorentz attributed to the electron. We are saved a further integration to find the energy content of this magnetic field because classical physics tells us that the energy in a loop of magnetic flux Φ threaded by a current i is $\frac{1}{2} i \Phi$. Taking the figures for the velocity of the orbiting electron from Bohr's theory, we find that the energy content of the quantum fluxoid is exactly half the kinetic energy of the electron. Now according to Lorentz, the kinetic energy resides in the magnetic field generated by the electron's motion. We come to the conclusion that the principle of equipartitioning of energy must occur so that the energy in the magnetic field of the electron is split equally between that part which moves with the electron and that part which is stationary within the orbit.

If we now return to Lorentz's model, we see that half the energy of the magnetic field of a moving electron is within a spherical surface of twice the radius of the electron.

Historical reconstruction

Now let us imagine that we are back in 1917 trying to solve the problem of the nature of atomic spectra. It is a different 1917 from that recorded in history. Lorentz's theory of electromagnetic mass has been accepted and incorporated into a theory of relativity based on the work of Lorentz and Poincaré. The quantization of magnetic flux has been discovered. Short lengths of tinned copper wire cooled to superconducting temperatures and their magnetic moment measured. They are treated as solenoids and their magnetic flux Φ is calculated from their magnetic moment. The results are all integer multiples of $\Phi_0 = 2.07\ldots \times 10^{-15}$ Weber, a quantity now known as the quantum fluxoid.

From a classical point of view, the orbiting electron should form a current loop containing magnetic flux Φ. The current in the loop is $i = \nu q$ where ν ("nu") is the frequency (orbits per second) and q the charge of the electron.

Suppose that the current loop contains a magnetic flux $\Phi = n \Phi_0$, then its energy content will be:

$$\tfrac{1}{2} i \Phi = \tfrac{1}{2} \nu q n \Phi_0$$

If we now assume equipartitioning of the electron's kinetic energy between that part of the magnetic field which moves with the electron and that part which is stationary within the orbit. The kinetic energy of the electron is $\nu q n \Phi_0$. The Virial theorem states that the time averaged potential energy of a system is half its total energy. We know the total energy is negative because the electron is bound and the Virial theorem is expressed in terms of the kinetic energy K giving the energy of the system as $-K$ and the potential energy as $-2K$. Now the potential energy is known from Coulomb's law and we can write:

$$\frac{-q^2}{4\pi\varepsilon_0 r} = 2\nu q n \Phi_0 \quad (1)$$

We can also write the kinetic energy as $\frac{1}{2} m u^2$ where $u = 2\pi r \nu$ is the electron's velocity.

$$\frac{1}{2} m (2\pi r \nu)^2 = \nu q n \Phi_0 \quad (2)$$

We can solve equations (1) and (2) to give:

$$r = n^2 \frac{4\varepsilon_0 \Phi_0}{\pi m} \qquad \nu = \frac{1}{n^3} \frac{q m}{32 \Phi_0^3 \varepsilon_0^2}$$

These are the equivalent of Bohr's result which may be obtained by substituting $\Phi_0 = \frac{h}{2e}$, the modern definition of the fluxoid quantum.

Now that we have a value for ν we can calculate the energy of the orbiting electron:

$$\mathcal{E}_n = \nu q n \Phi_0 = \frac{-1}{n^3} \frac{q m}{32 \Phi_0^3 \varepsilon_0^2} q n \Phi_0 = \frac{-1}{n^2} \frac{q^2 m}{32 \varepsilon_0^2 \Phi_0^2}$$

Again, substituting of $\Phi_0 = \frac{h}{2e}$ yields the familiar result from the Bohr theory.

Analysis of atomic spectra has revealed a relationship of the form $\frac{1}{n^2} - \frac{1}{l^2}$ between the frequencies of the spectral lines and it is not hard to conclude that there is a link between frequency and energy.

Photons

It was already established that light came in photons and that the energy of a photon was $h\nu$. Bohr's theory makes the link, but never really explains why the photon's frequency should be governed by this relationship.

In our historical reconstruction, we can see that there is a definite relationship between quanta of magnetic flux, charge and energy. We know from Maxwell's laws that magnetic flux comes in loops and that magnetic flux moving at the speed of light generates an electric field with regions of displacement charge at its ends. We will now make a bold assumption: that each half phase of a photon must be composed a quantum fluxoid and that it forms a half phase because its associated electric flux is also quantised.

So we make the even bolder assumption that there is an electric flux quantoid $\Psi_0 = \frac{e}{N}$ where e is the charge on the electron and N is an integer to be determined. (We would hope that at a later date, we would be able to understand how N, $\frac{1}{3}N$ and $\frac{2}{3}N$ electric flux quantoid fit together to form electrons U and D quarks.)

Now let us consider a circular loop radius r of magnetic flux $\Phi = \delta l \, \delta r \, B$ with rectangular cross section $\delta l \times \delta r$ moving at the speed of light together with its electric flux $\Psi = 2\pi r \, \delta l \, D$. The energy densities of the electric and magnetic flux will be $\frac{1}{2} D E$ and $\frac{1}{2} B H$. The fields are related by induction laws $E = c B$ and $H = c B$ resulting in the two energy densities being both equal to $\frac{1}{2} c D B$. Thus the energy of the loop is $\mathcal{E} = 2\pi r \, \delta l \, \delta r \, c D B$ and since $\Psi = 2\pi r \, \delta l \, B$ and $\Phi = \delta l \, \delta r \, B$ we can simplify this to give:

$$\mathcal{E} = \frac{c \Psi \Phi}{\delta l}$$

Noting that the frequency ν and wave length λ are related by $\nu = \frac{c}{\lambda}$ we make the obvious deduction that the energy of a photon is proportional to its frequency if all photons contain an equal number of half phases each consisting of a magnetic flux quantoid and and electric flux quantoid.

We have carried out this analysis for what is essentially a "square wave" photon, but interference experiments are best explained assuming light is sinusoidal. We are not at liberty to alter γr because that is controlled by the inductance laws and depends on r. What we can do is assume that the flux densities are sinusoidal and use integration. Unfortunately a factor of $\frac{\pi^2}{8} \cong \frac{10}{8}$ emerges. However only a very slight variation on the sine wave shape would be needed to correct for this.

Flux tunnels

The next surprise comes when we calculate the magnetic field strength of the quantum fluxoid. We have already said that it just fits inside the electron orbit leaving a tunnel just under twice the radius Lorentz attributed to the electron.

$$a = \frac{\mu_0 q^2}{6 \pi m} = 1.878 \times 10^{-15}$$

Calculating the magnetic field strength of the tunnel wall:

$$B = \frac{\mu_0 n \nu q r}{2 a \pi} = 6.3 \times 10^9$$

It is normal in atomic calculations to meet quantities which are many orders of magnitude smaller than anything we encounter in the macroscopic world. To meet a magnetic field strength 10 orders of magnitude greater than those normally encountered defies the imagination. If an electron could move through a field of this strength with the velocity of an orbiting electron in a hydrogen atom, it would experience an acceleration of 2.43×10^{27} metre/sec^2. Dividing that by the acceleration of an electron orbiting the hydrogen atom gives 26900. We conclude from this if the field of the quantum fluxoid has a degree of stability, it is able to exert guiding forces on the electron 3 or 4 orders of magnitude greater than the electrostatic forces.

The picture of the ground state orbit of hydrogen that emerges is one of a single magnetic entity in the shape of the field surrounding a current loop. The part field passing through the centre of the loop reaches out far beyond the atom. The critical scale is the distance light travels in the time it takes the electron to make one orbit: 4.5×10^{-8}. Loops longer than this cannot respond to the instantaneous motion of the electron. Since the quantum fluxoid is a single entity part of which extends beyond this range, it is anchored within the orbit and given stability. But the vast bulk of the substance of the fluxoid forms this guiding tunnel around which the electron orbits. Long term, the electron controls the position and form of the tunnel, but at a time scale of a fraction of the orbital period, it is the tunnel which controls the electron.

Higher orbitals

Let us now examine the dependence on n and see how closely the results mirror the Bohr model. The "fluxoid atom" has stable solutions for integer numbers of quantum fluxoids. We have seen that $r = n^2 \frac{4 \varepsilon_0 \Phi_0}{\pi m}$ and $\nu = \frac{1}{n^3} \frac{q m}{32 \Phi_0^3 \varepsilon_0^2}$ following from the assumption that each allowed state contains n quantum fluxoids.

The total energy of the system in that state is negative and numerically equal to the kinetic energy. We have seen that this is $\nu q n \Phi_0$, but it is perhaps easier to understand if we introduce the current equivalent $i = \nu q$. If we take into account the fact that $\nu \propto \frac{1}{n^3}$ we may write:

$$i_n = \nu_n q \qquad i_n = \frac{i_1}{n^3} \qquad \mathcal{E} = -\frac{i_1}{n^3} n \Phi_0$$

Remembering the relationship between energies, we see that for $n = 2$, half the kinetic energy is now contained two quantum fluxoids each of $\frac{1}{8}$ the energy content of the ground state fluxoid. The "tunnel length" of each fluxoid is twice that of the ground state fluxoid giving a path length four times that of ground state.

We find that this set of relationships simply scales the numerical integrals used to calculate how the fluxoids fit within the orbital path. The current is reduced by $\frac{1}{n^3}$ but the flux is proportional to r which is increased by a factor n^2. Since n fluxoids must be fitted inside the orbit, the integral is independent of n and the tunnel diameter is unaltered.

The n_{th} tunnel therefore consists of n sections of tunnel each formed by a fluxoid of $\frac{1}{n^3}$ the energy content of the ground state fluxoid. The n fluxoids contain half the kinetic energy of the electron, the rest being contained in a the magnetic field surrounding the electron and moving with it. The size of the tunnel is such as to make a tight fit guiding the electron on its path.

Fine structure

I had at first thought that the fluxoids would be divided along the length of the tunnel so that the orbiting electron would pass through each fluxoid in turn. This would not explain the fine structure of the hydrogen spectrum. When viewed under high magnification, each spectral line is found to consist of several thinner lines. In the presence of a magnetic field, these spread out indicating that the fine structure is due a magnetic property of the orbit. The Somerfield model of the hydrogen atom explained fine structure as due to elliptical orbits, but is logically flawed in that its ground state requires that the electron does not orbit the nucleus, but oscillates back and forth passing through the nucleus. The fine structure can be explained more simply by the fluxoid model if we allow for different ways of fitting the fluxoids into the orbit.

We need to consider the orbiting electron as a current loop threaded by a small number of quantum fluxoids. The normal symmetry of the "far field" of a macroscopic current loop some centimetres in diameter no longer applies. We have a choice as to how to insert several fluxoids. At least one must tightly wrap the path of the electron and is unable to be part of the far field. The fine structure results from the magnetic moment of the orbiting electrons current loop. The interaction of macroscopic current loops which we attribute to their magnetic moment results from changes in the quantity of flux threading both loops. Since this constitutes a vast number of individual fluxoids, the classical understanding of magnetic moment holds good. When we come to the scale of electron orbits threaded by only a small numbers of fluxoids, the concept is misleading. If we have an orbit containing say 3 fluxoids, 1, 2 or 3 of them might tightly wrap the path of the electron. If 1 fluxoid tightly wraps the path, the 2 remaining fluxoids are free to interact with external magnetic fields. If two fluxoids tightly wrap the path, only one is left to interact with external magnetic fields. We arrive at the equivalent of the Bohr quantum numbers n and l.

Helium

I have had some success in applying this model to the helium atom. If we assume that two electrons can share the same fluxoid tunnel always being on opposite sides of the nucleus, the ground state with only one fluxoid threading the orbits gives an energy level of -83.3 electron volts compared to the experimentally determined value of 79.0 electron volts. One possibility is that the electrons might find it easier to squeeze through the tunnel if one follows the other more closely. The reduced distance between the two electrons changes the potential energy.

Another possibility is that the orbits of the two electrons to thread one another. The energy levels are far more difficult to calculate because we do not know the extent to which the magnetic fields are able to stabilise the orbits or the force between the electrons to perturb them. We can obtain the correct answer with well behaved orbits inclined at $\frac{\pi}{5}$ radians to each other.

Protons and neutrons

To my utter amazement, when we apply the fluxoid concept to the 3 quark model of nucleons, with the two similar quarks orbiting the third quark within the same fluxoid tunnel, the diameter of the orbits is reasonably close to their assumed diameters.

