SECTION 13

The End of Particle "Spin" and Its Quantized Angular Momentum

<u>*THE PROBLEM*</u>

<u>The Stern-Gerlach Experiment</u>

As the name suggests, particle spin was conceived as the rotation of a particle around an internal axis. This spin obeys the same mathematical laws as quantized angular momenta do. On the other hand, spin has some peculiar properties that distinguish it from orbital angular momenta.

Particles with spin can possess a magnetic dipole moment, just like a rotating electrically charged body in classical electrodynamics. Or, rather, individual particles exhibiting a magnetic dipole moment are deemed particles having spin. These magnetic moments can be experimentally observed in several ways, e.g. by the deflection of particles by inhomogeneous magnetic fields in a Stern-Gerlach experiment, or by measuring the magnetic fields generated by the particles themselves.

If the particle is treated as a classical magnetic dipole as it moves through a homogeneous magnetic field, the forces exerted on opposite ends of the dipole cancel each other out and the trajectory of the particle is unaffected.

However, if the magnetic field is inhomogeneous then the force on one end of the dipole will be slightly greater than the opposing force on the other end, so that there is a net force which deflects the particle's trajectory.

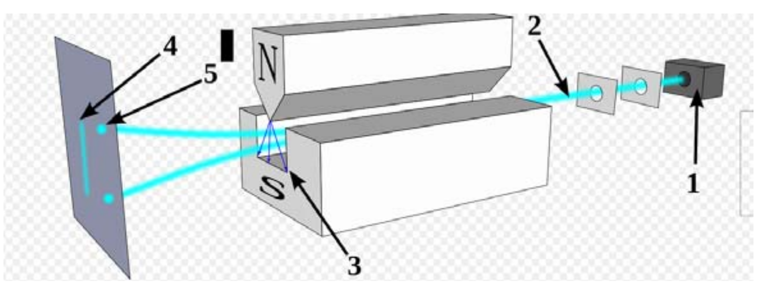

Figure 13-1
The Stern Gerlach Experiment

1 – Furnace 2 – Collimated beam 3 – inhomogeneous magnetic field
4 – Expected (not quantized) result 5 – "Quantized" result

The Stern-Gerlach experiment is normally conducted using silver atoms. That is because silver can be melted and then vaporized at a relatively low temperature. In the Stern-Gerlach experiment, Figure 13-1 above, silver is vaporized at a high temperature such that the atoms of the vapor are at high energy. Those atoms that escape from the furnace through a small aperture are collimated by further apertures into a narrow beam of silver atoms. The beam is then directed into an inhomogeneous magnetic field.

If the particles were classical spinning objects, one would expect the distribution of their spin angular momentum vectors to be random and continuous. Each particle would be deflected by an amount proportional to its magnetic moment, producing some density distribution on the detector screen. Instead, the particles passing through the Stern-Gerlach apparatus are deflected either up or down by a specific amount as shown in the figure.

This was taken to be a measurement of the quantum observable now known as spin angular momentum, which demonstrated possible outcomes of a measurement where the observable has a discrete set of values.

Historically, this experiment was decisive in establishing the physics concept of the reality of angular momentum quantization <u>in all atomic-scale systems</u>. It was the justification for the explanation of atomic fine and hyperfine spectra. It was the justification for contending that the stable atomic electron orbits were those for which the orbital angular momentum was an integer multiple of a fundamental angular momentum of $h/_{2\pi}$.

The preceding Section 11 has demonstrated that quantized angular momentum and particle "spin" are not the correct explanation of the fine and hyperfine spectra and the just preceding Section 12 has demonstrated that it is integer multiples of the orbiting electron's matter wavelength, not angular momentum, that accounts for the stable electron orbits.

Now it shall be found that "spin" and quantized angular momentum are not what is involved in the apparently quantized result of the Stern-Gerlach experiment, as follows.

THE CAUSE OF THE STERN-GERLACH APPARENT QUANTIZATION

In the Stern-Gerlach experiment the metal silver is an excellent conductor of electricity. The reason is that its outermost orbital electron is very loosely bound to its atom. As a result that electron tends to become a free electron able to readily travel within the silver metal in which it is found. As the temperature and, therefore, energy increases in the quite hot and energetic silver vapor of the furnace the silver atoms of the collimated beam are mostly ionized, lacking that outer orbital electron.

Those positive silver ions flowing in a collimated beam constitute an electric current. And, in accordance with Ampere's Law that current results in a concentric magnetic field making each flowing silver ion a magnetic dipole. It is not "spin" nor a "natural property" of particles that produces the magnetic dipole, it is merely Ampere's Law and the ionized silver atoms.

But, the electrons lost by the ionized silver atoms are still present and flowing in the collimated beam. The beam is overall electrically neutral. That means that some of the silver atoms temporarily acquire an extra electron and become negative ions. And, the Ampere's Law magnetic field of the negative ion current flow produces a magnetic dipole directed opposite to that of the current of positive ions.

The collimated beam of silver atoms is a beam of magnetic dipoles of equal strength and opposite orientations. The strength of each is due to either one electron too few [for positive ions] or one electron too many [for negative ions], a quantizing of the magnetic dipoles and therefore of their consequent deflection in the inhomogeneous magnetic field.

In brief the effect as if the silver atoms have "spin" and quantized angular momentum is due to their loosely bound outer electrons and their migration within the silver atom beam resulting in individual silver ions' local Ampere's Law current and consequent magnetic dipole.

THE END OF PARTICLE "SPIN" AND ITS QUANTIZED ANGULAR MOMENTUM

As presented earlier above, in discussions of Quantum Mechanics a property of particles identified as "spin" and involving angular momentum occurs frequently as for example a referring to "spin" up or "spin" down as quantum angular momentum 'states'. In those discussions it is often stated that no specific rotary motion (spin) is necessarily involved but that rather some intrinsic property of the particle being treated, an electron or an atom, is what is intended.

The intent is that quantized angular momentum is a natural property of particles such as electrons or atoms and that is contended in spite of there being no cause or mechanism for the particles to have that property and with the actual denial that any physical spin as rotation about a central axis is present.

That contention is defended by citing three different experimentally revealed behaviors:

- atomic spectra fine and hyperfine structure;
- atomic electron specific stable versus unstable orbits;
- the Stern-Gerlach experiment.

It has now been shown in Section 11 for atomic spectra fine and hyperfine structure, and in Section 12 for atomic electron specific stable versus unstable orbits, and in the current Section 13 just above for the Stern-Gerlach experiment, that there is no valid basis for the contending that quantized angular momentum is a "natural property" nor any valid basis for the general attribution of "spin".

THEN WHAT ABOUT "SPINTRONICS" ?

Spintronics is the study of the intrinsic spin of the electron and its associated magnetic moment. It has already been found here that fundamental particles, those which are Spherical-Centers-of-Oscillation, cannot spin and do not have "spin" as a "natural property".

However, the electron is a negatively charged particle that is always in motion. The most frequent appearance of its motion is in atomic electron orbits. But, free electrons are abundant, never at rest, always in curvilinear motion and that motion is effective as an electric current which results in a magnetic moment, which is the subject of spintronics.

Spintronics is not about a "natural occurring property" of electrons but merely the effect of it being a charge in constant motion acting per Ampere's Law. That is not a new Quantum effect, merely the classical action of classical physics. Any apparent quantization must be accounted for by some cause, some mechanism. It cannot appear without cause or mechanism as simply a "natural property".