# What is Electron Spin?

Kamal L Rajpal



*ABSTRACT*

*An isolated static electron in free space is not a fixed particle at rest. It is always oscillating in a SHM in its own electromagnetic inertia field, rest frame even at zero kelvin temperature. This is non-thermal, standing wave, resonance Compton frequency, oscillation along a linear path or, along an elliptical or a circular (clockwise or anti-clockwise) path, corresponding to the electron's intrinsic magnetic moment (spin up or spin down).*

*An electron with spin behaves like a tiny magnet. Intrinsic spin does not imply that a subatomic particle is spinning like a toy-top about its axis. A hypothetical electron without a charge is like the bob of a simple pendulum without a string.*

## INTRINSIC SPIN & ORBITAL ANGULAR MOMENTUM

Subatomic and atomic particles carry energy and angular momentum. Angular momentum has two components:

> Intrinsic spin angular momentum (SAM) and
> Orbital angular momentum (OAM).

The SAM of the earth gives us day and night. The OAM of the earth gives us the seasons, as the earth moves around the sun.

Spin is a fundamental property of atomic and subatomic particles, like its mass or charge. It is a quantum mechanical property and is present both in moving and in particles at rest. OAM results from the motion of a particle around some object, like an electron around a nucleus.

Spin is the intrinsic angular momentum of a particle which exists even when the particle is at rest, as distinguished from the orbital angular momentum (OAM). An electron has an intrinsic angular momentum and a consequent intrinsic magnetic moment or spin. The observed electron spin angular momentum, implies that the electron is a tiny magnet.

Intrinsic spin does not imply that a subatomic particle is spinning like a toy-top about its axis. Spin corresponds to the circular or elliptical oscillations of a subatomic particle. An analogue in classical mechanics is the “conical pendulum” (to be explained below).

In atomic or subatomic particles, the intrinsic spin angular momentum is quantized. For particles of a given kind, it always comes in fixed discrete units that are integer multiples of ½(*h-bar*). For ease of expression, a particle with spin ½(*h-bar*) is referred to as having ‘*spin* ½’. Also, the electric charge is quantized and comes in simple multiples of the fundamental unit of electron charge.

The intrinsic spin of an electron and a photon have only two quantum mechanical states. For an electron this refers to spin-up or spin-down, that is, clockwise or anticlockwise oscillations. For a photon it corresponds to clockwise or anticlockwise, circular or elliptical polarization.

## THE ELECTRON

An electron is a subatomic elementary particle with the smallest non-zero rest mass. It has a negative electric charge, which generates a field in free space, extending to infinity, and is conversely acted on by forces due to the field.

Assume an isolated electron in free space to be at rest, at the origin in a given inertial frame of reference. Let this electron be subject to a tiny force F in the (+) Y-axis direction.

***A uniformly accelerating electron*** *gives rise to*
***a uniformly changing electric field****. This will induce*
***a uniformly changing magnetic field****, which will induce*
***a uniformly changing electric field****, so as to oppose the initial change in the electric field.* This will cause the electron to decelerate and come to rest at some point (+a) on the Y-axis.

The decelerating electromagnetic force on the electron will continue to act in the plus (+) Y-axis direction and cause the electron to accelerate in the minus (-) Y-axis direction. Since, deceleration in the plus (+) Y-axis direction is equal to acceleration in the minus (-) Y-axis direction. The electron will accelerate towards the origin.

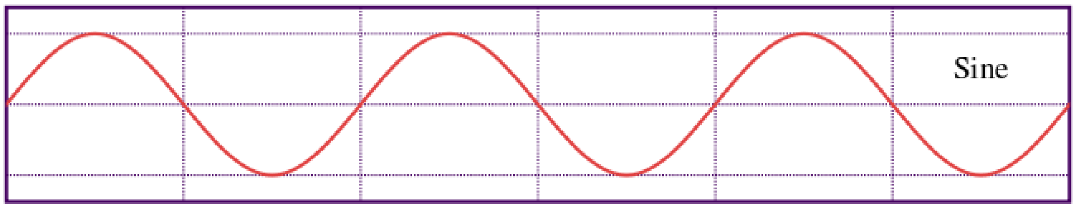
The initial force F will now be acting in the minus (-) Y-axis direction. This force will carry the electron to a point 'minus a' (-a) on the Y-axis, where the electron will come to rest, change direction and accelerate towards the origin. And so on.

http://upload.wikimedia.org/wikipedia/commons/7/74/Simple_harmonic_motion_animation.gif

- *An isolated static electron in free space is not a fixed particle at rest. It is always oscillating in a SHM in its own electromagnetic inertia field, rest frame.*

An electron which is oscillating along the Y-axis, in a SHM, with its rest or fixed mean or equilibrium position at the origin; when subject to a force in the (+) X-axis direction at the origin, will move along a sine wave path in the XY-plane, in the (+) X-axis direction, even at relativistic velocities.

- *A classical particle moves along a linear path as per Newton's laws. An atomic or a sub-atomic particle moves along a sine wave path as per Schrodinger wave equation.*




- *An electron moves, not in a straight line but, along a sine wave path. This explains the physical concept of the wave-particle nature of the electron.*

However, a hypothetical electron with zero electric charge, at rest at the origin in a given inertial frame of reference, when subject to a force in the (+) X-axis direction, will move with a uniform motion in a straight line in the (+) X-axis direction as per Newton's laws.

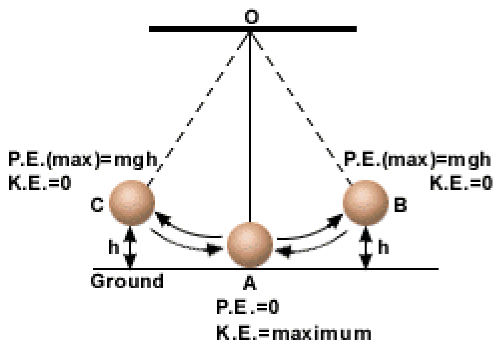
- *A hypothetical electron without a charge is like the bob of a simple pendulum without a string.*

The intrinsic electromagnetic oscillation nature of an isolated electron in free space, is in accordance with the law of conservation of energy and is similar to an ideal simple pendulum oscillating in a SHM in the earth's gravitational field.

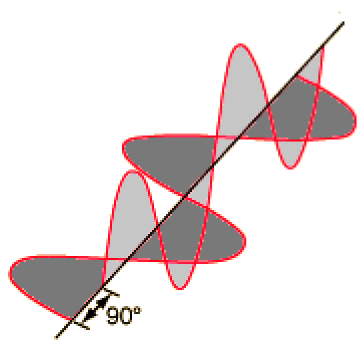
When a pendulum is displaced sideways from its rest or equilibrium position it is subject to a restoring force due to gravity that will accelerate it back toward the equilibrium position.

The *potential* (gravitational) field vector direction (Y-axis) and the *kinetic* (velocity) field vector direction (X-axis), of a SHM oscillating ideal simple pendulum are *orthogonal*. The potential field and the kinetic field are in *phase quadrature*.

This implies that when the potential energy is maximum, the kinetic energy or velocity is zero. And, when the potential energy is minimum, the kinetic energy or velocity is maximum. The potential energy plus kinetic energy is always a constant.




Similarly,




The transverse electric (E) and magnetic (H) fields of a SHM oscillating electron (at rest or uniformly moving) are orthogonal and in phase quadrature. The electric field energy plus magnetic field energy is always a constant.

This SHM, standing wave, intrinsic electromagnetic inertia generating resonance is at the electron Compton frequency, as per de Broglie. The electron rest mass is equivalent to the energy of a photon of wavelength equal to the electron Compton wavelength. An analysis of the oscillating electron is also given by Petr Beckmann [1].

The earth's conservative gravitational field is external to the simple pendulum. However, an electron oscillates in a SHM, in its own electromagnetic inertia field, even at zero Kelvin temperature.

Oscillations can be thermal or electromagnetic. Thermal oscillations tend to zero as the temperature tends to zero kelvin. At zero kelvin we are left with only the electromagnetic oscillations.

This is non-thermal, zero point vibration at absolute zero. The zero point energy is the lowest possible vibration energy. By wave mechanics, the zero-point energy for a linear simple harmonic oscillator of frequency ($f$) is $\frac{1}{2} hf$, where ($h$) is the Planck constant.

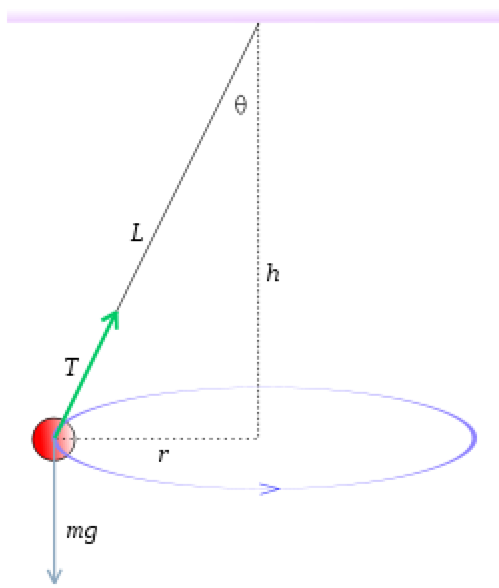
As per Galileo's law of inertia or Newton's first law of motion, a physical body is either at rest in a given inertial frame of reference or will continue to move with a uniform motion in a straight line with a constant velocity. Similarly, an ideal simple pendulum is either at rest or will continue to oscillate for ever in a SHM, unless acted upon by an external force to change it.

An isolated electron in free space is always oscillating in a SHM in its own rest frame. This non-thermal, SHM, standing wave, intrinsic electromagnetic inertia, resonance Compton frequency, oscillation is as fundamental as:

- The uniform motion in a straight line, law of linear inertia or the conservation of linear momentum and,

- The law of rotational inertia or the conservation of angular momentum.

An ideal simple pendulum will oscillate in a SHM along a linear path or, along an elliptical or a circular path (*conical pendulum*). Similarly, an electron oscillates in a SHM along a linear path or, along an elliptical or a circular (clockwise or anti-clockwise) path, corresponding to the electron's intrinsic magnetic moment (spin up or spin down). An electron with spin behaves like a tiny magnet.

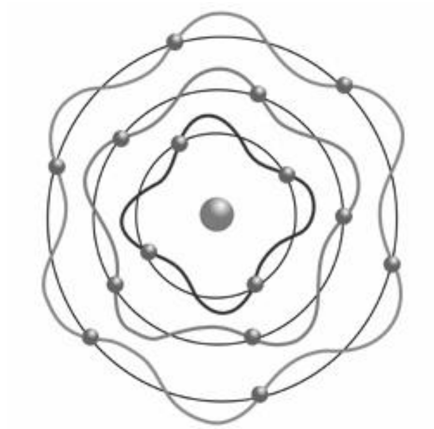



A ***conical pendulum*** is a simple pendulum in which the bob moves at a constant speed in a horizontal circle with the string tracing out a cone. The time period, for a very small radius of swing only, is the same as for the simple pendulum wherein the bob is swinging back and forth in a vertical plane.

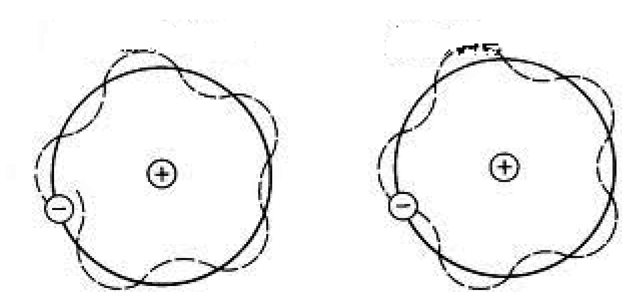
## ATOMIC ORBITS

Since an electron does not move in a straight line but along a sine wave path, so, *electrons in atomic orbits do not move in a linear circular path but along a sine wave, circular path* [1]. The actual path is on a 2D orbital surface around the nucleus.

The highest point on a wave is called the peak. The lowest point is called the trough. As the electron orbits the nucleus the energy required to escape the atom would be less when it is at the highest peak point. Quantum tunneling is more likely to occur at the peak and unlikely at the lowest trough point.



If, the electron orbit circumference is an integral multiple of the electron de Broglie wavelength; the electron which is moving in a sine wave circular path, will repeat the same sine wave path in each successive orbit. The sine wave paths in consecutive orbits will exactly overlap. The electron wave reconnects with itself. *The electric (E) and magnetic (H) fields oscillate in space and time but do not travel in space and time. This is a stable standing wave electron orbit.* The orthogonal E and H fields are in phase quadrature.



Not a Standing Wave Standing Wave

If, the electron orbit circumference is not an integral multiple of the electron de Broglie wavelength, the sine wave paths in successive orbits do not overlap. The electron wave does not reconnect with itself. The electric (E) and magnetic (H) fields travel in space and time along the electron orbit circumference. It is <u>not</u> a standing wave and so is an unstable electron orbit.

REFERENCE

[1] Beckmann Petr, Einstein Plus Two, The Golem Press, Boulder, Colorado, USA, 1987. (Copies from: Irene Beckmann, P.O. Box 1342, Boulder, CO 80306, USA).

09 December 2002. Revised: 16 June 2013.

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webmaster@physicsphotons.org