

The Classical Atom Project

To understand concepts proposed in this presentation,
please first review the presentations:

[Spin Wave Technology](#)

and

[An Exploitable Link between Electromagnetism and Gravity](#)

In-Work document

Migrated all slides related to the Equivalence Principle to a separate file of the same name. Jump to slide 36 for animation, simulation, classical modeling terms of endearment

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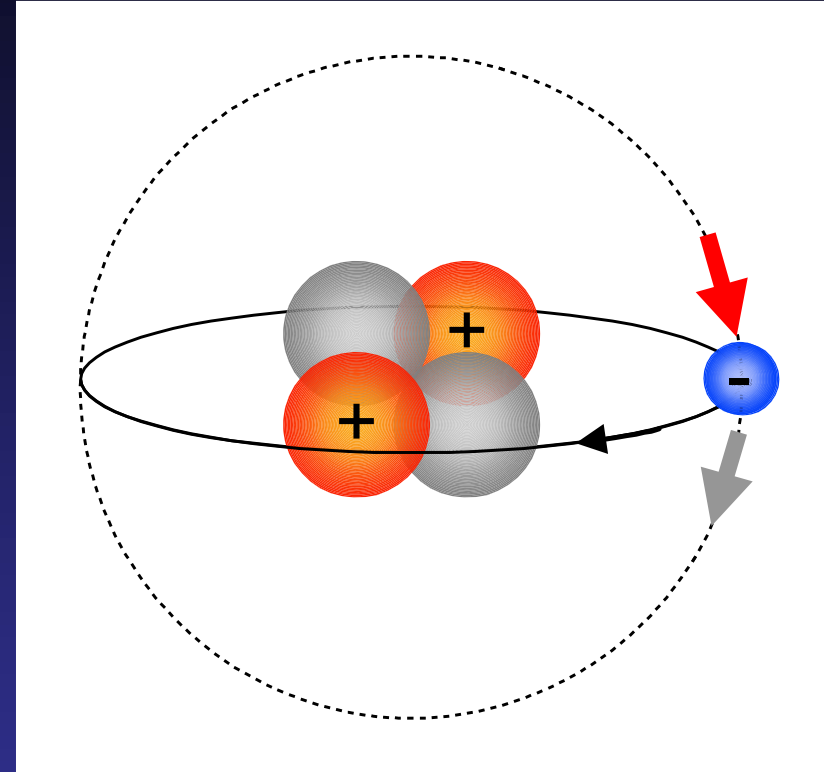
The Purpose of this Project

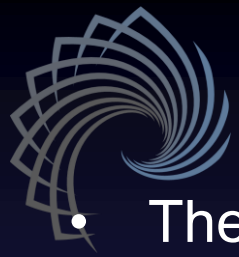
- To see if it is possible to build a working atom with classical laws.
- This was first proposed in the presentation [Spin Wave Technology](#) created more than 20 years ago.
- I happened to be home alone (really just alone in my lab) with nothing else better to do so I thought I would see how hard it would be to build a classical atom.
- This research starts with a few classical assumptions like:
 1. If charged subatomic particles should radiate away electromagnetic energy from their motions, then they do and they absorb just as much energy from all other charged particle emissions in the universe.
 2. In the diagrams that follow, let's assume the atom is cooled to absolute zero, so diagrams of classical motions are more repetitive with less thermal randomness, like a [time crystal](#) but in a classical way.

Patience please. I'm learning quantum mechanics as I go.

Let's Start with a Positive Helium Ion

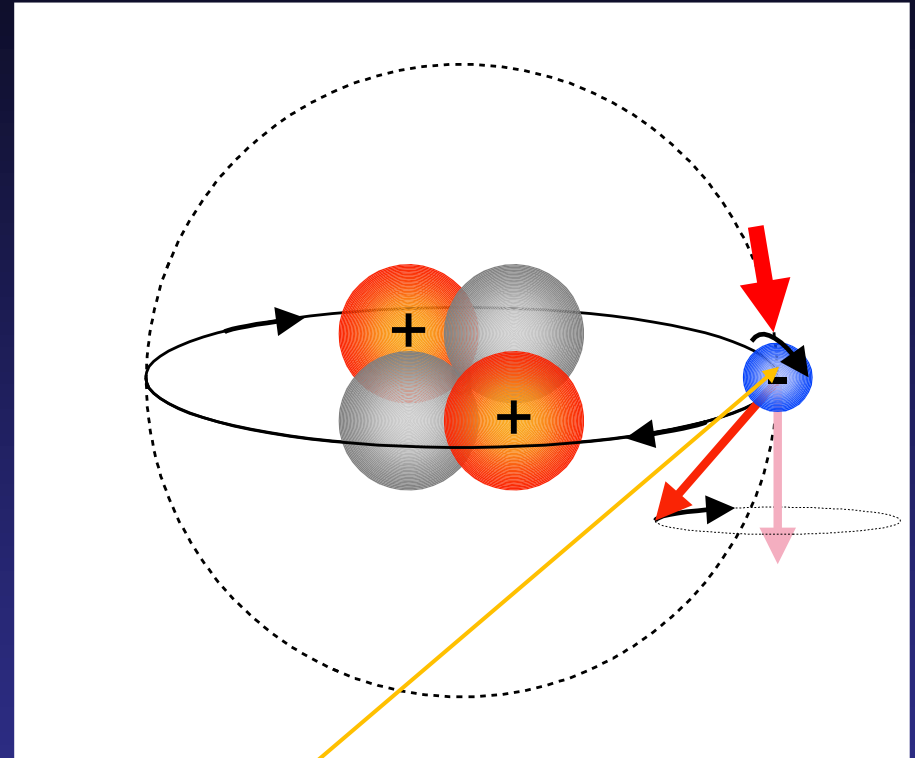
- Using a classical electron as described in [Spin Wave Technology](#) ,
- No matter what direction this electron moves within the 1s orbital, its motion relative the positive protons of the nucleus will cause an apparent magnetic field to come from the protons, from the moving electron's point of view.
- In this example, if the electron is moving out of the screen, it is equivalent to the positive protons moving into the screen from the electron's point of view.
- Per [Ampère's right-hand grip rule](#) for **positive** charges, a magnetic North will be felt by the electron from the top and a South field at the electron's bottom.





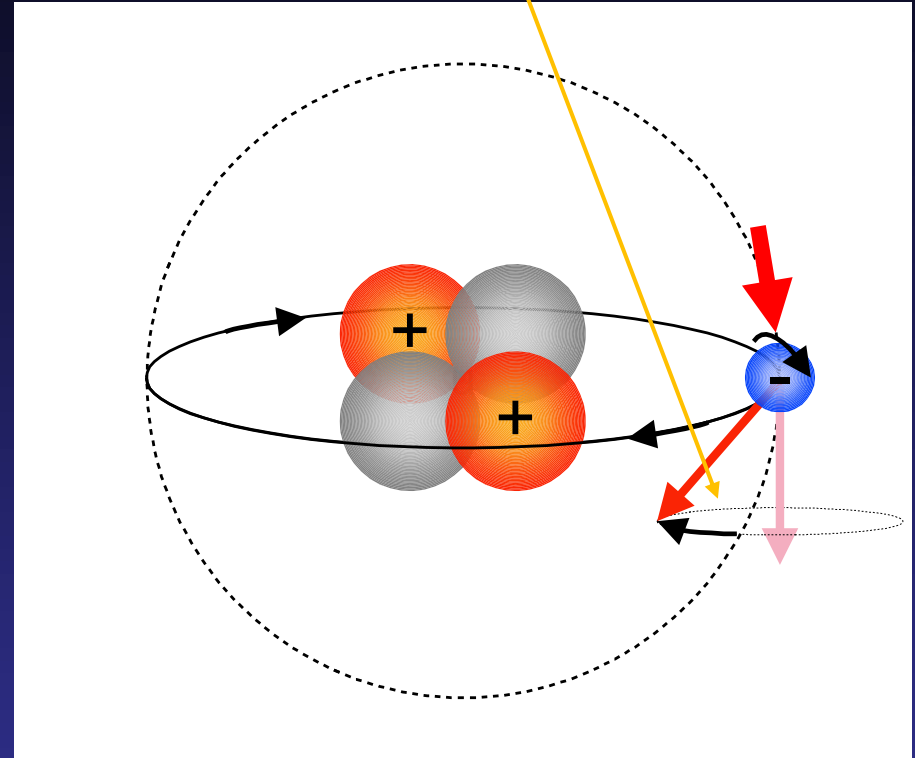
Analyzing the Orbital Electron's Orientation

- The electron's magnetic dipole will naturally attempt to align with the perceived magnetic field from the positive charges of the nucleus.
- It will also precess like a top or gyroscope due to the pull of the apparent magnetic field and due to the influence of the sea of standing waves created by all precessing electrons everywhere as described in [Spin Wave Technology](#).
- Analyzing the electron's classical spin direction:
 - Using the [Left Hand Rule](#) for the current flow of **negative** charges, the classical electron spin direction is as shown when its magnetic North (red arrow, not pink arrow) is pointing as shown.



Analyzing the electron's magnetic dipole direction of precession

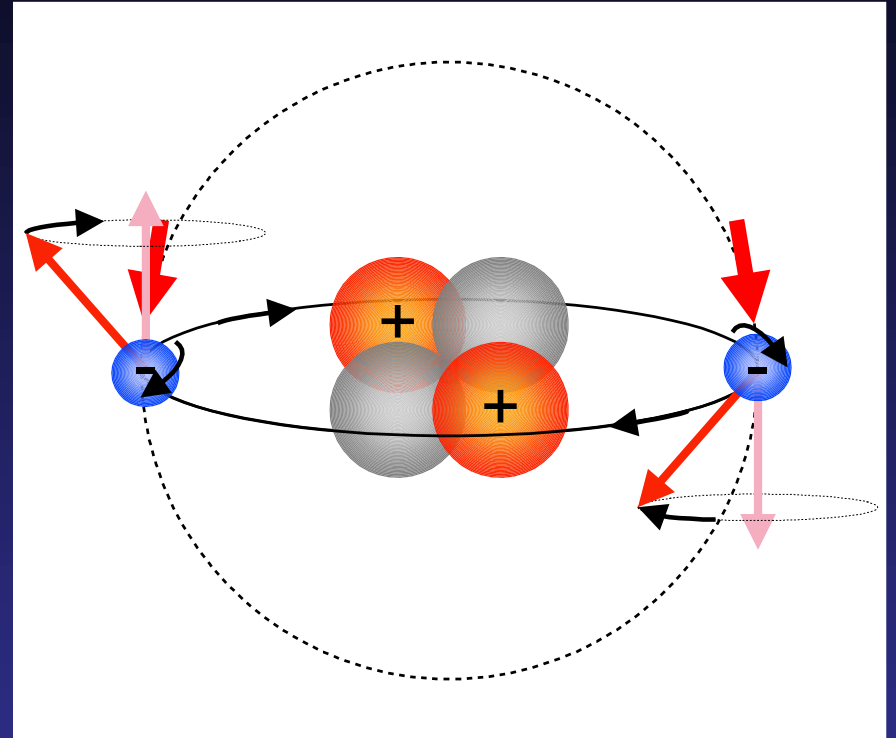
- When an electron's magnetic field is “aligned with” an external field, it precesses the opposite direction from when it is “aligned against” an external magnetic field.
- Visualize this with a tilted gyroscope with a bar magnet through its spin axis. Put this all inside a wire coil and change its direction of precession by changing the external magnetic field direction set by the direction of current through the coil.
- In this case, the electron's precession direction is kind of opposite its spin direction. It is “kind of” because they don't share the same axis.
- The electron's classical spin axis precesses around a precession axis, whereas quantum physics refers to the precession axis as the spin axis.





What happens when another electron comes along?

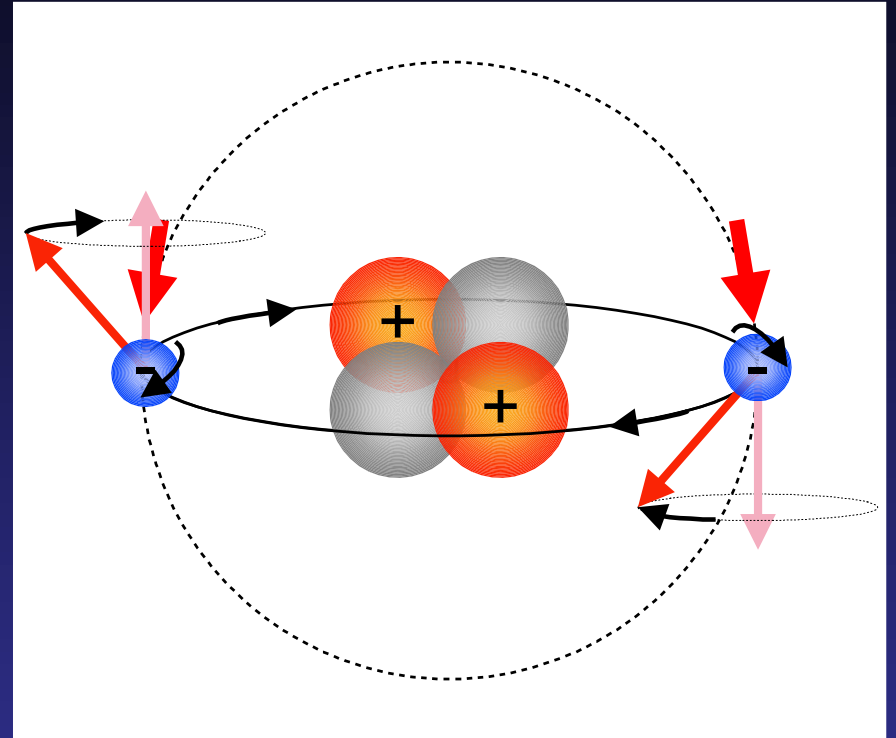
- Another electron will be electrostatically attracted to the positive charges in the nucleus.
- As it approaches, the magnetic force attempting to orient the new electron in the opposite direction of the first electron will be stronger than the apparent magnetic field of positive charges in the nucleus that is created by the relative motion.
- To visualize this strong force, dangle a bar magnet in the air and then tie a string around the center of gravity of a 2nd bar magnet.
- In any random orientation, bring the 2nd bar magnet close to the 1st.
- The magnetic forces will always align the 2nd bar magnet in the opposite direction. But use some padding to save them from damage.

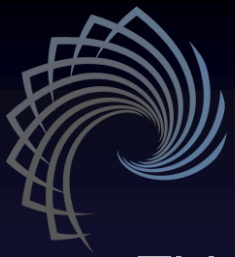




What happens when another electron comes along? *continued*

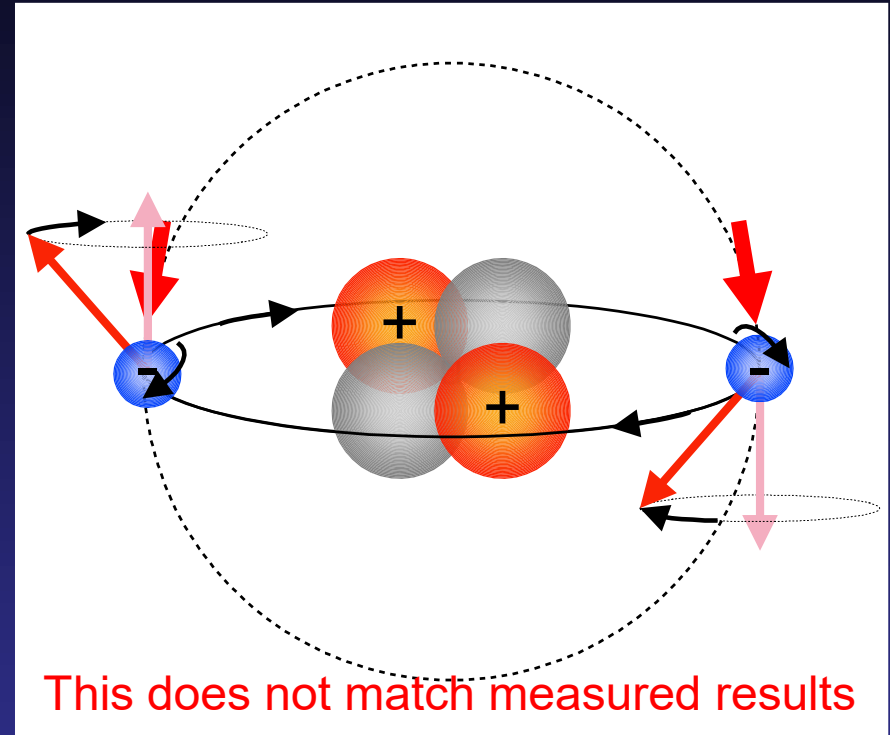
- The 2nd electron is electrostatically inhibited from orbiting towards the 1st electron, so it ends up orbiting in the same direction as the 1st electron.
- It will also have a natural tendency to orbit in a direction that is normal to the orientation of its axis of precession, which was already forced to be exactly opposite the orientation of the 1st electron.
- This forces them to share the same orbital plane even as this plane is free to be in any orientation within the 1s spherical orbital shell.
- The 2nd electron's orbital direction is into the screen causing the positive nucleus to be coming out of the screen from that electron's point of view, so the apparent magnetic field from the positive charges in the nucleus will be from the top also.



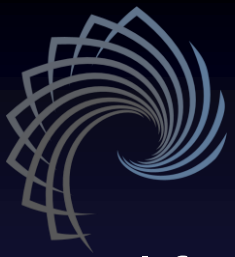


So far, Classical Results don't match reality

- This pushes on its magnetic dipole which causes it to precess also.
- This precession is kind of in the same direction as the electron spin.
- This causes both electrons to be precessing in the same direction.
- This is really bad news for the previously proposed gravity theory that required the precessions to be in opposite directions!!!
- Either I messed up directions somewhere or something else is happening or my gravity theory is flawed. ;^(

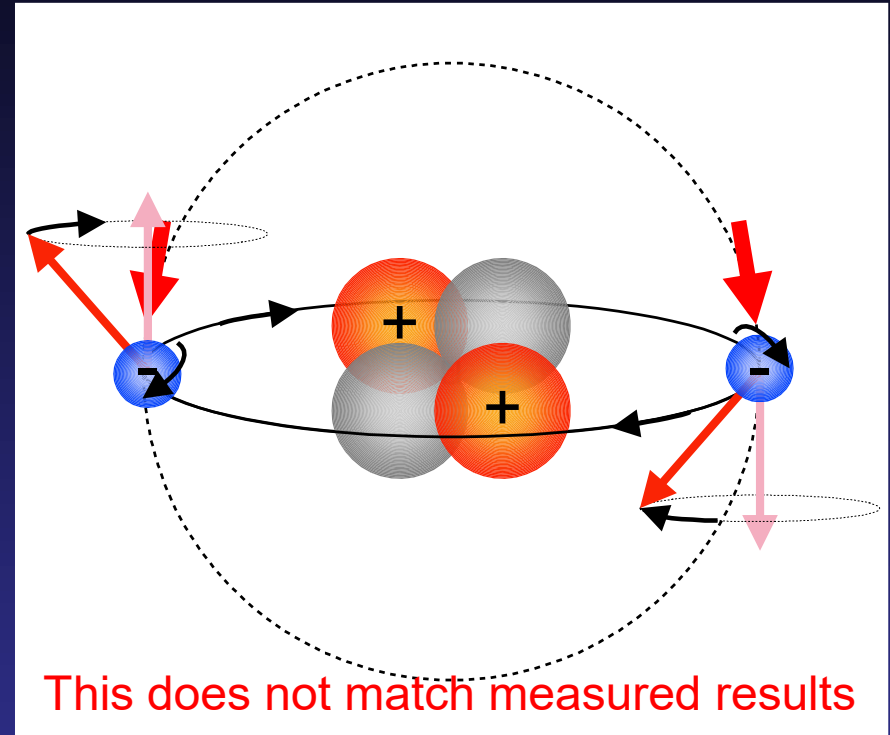


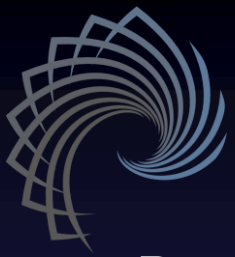
*See next slide after
a night's semi-sleep*



So far, Classical Results don't match reality

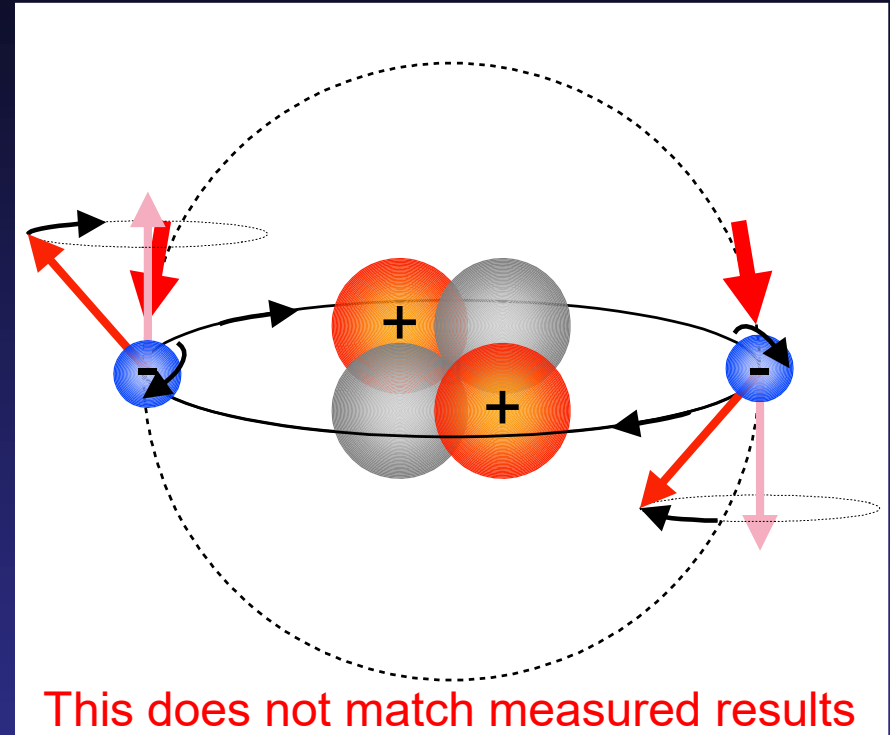
- I forgot a lot of things, starting with the influence of apparent magnetic fields between the 2 electrons.
- From the 2nd electron's point of view, relative motion causes the 1st electron to emanate its own magnetic field. This electron is half the charge of the nucleus and twice the distance to the 2nd electron but twice the relative speed of the nucleus.
- So, this is still not enough influence to completely negate or reverse the apparent magnetic field from motion relative the protons.
- The 1st electron will also experience an apparent magnetic field from relative motion of the 2nd electron. This will also reduce the North field from motion relative the nucleus but not negate or reverse it.

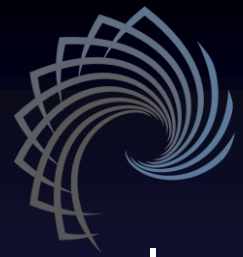




So far, Classical Results don't match reality

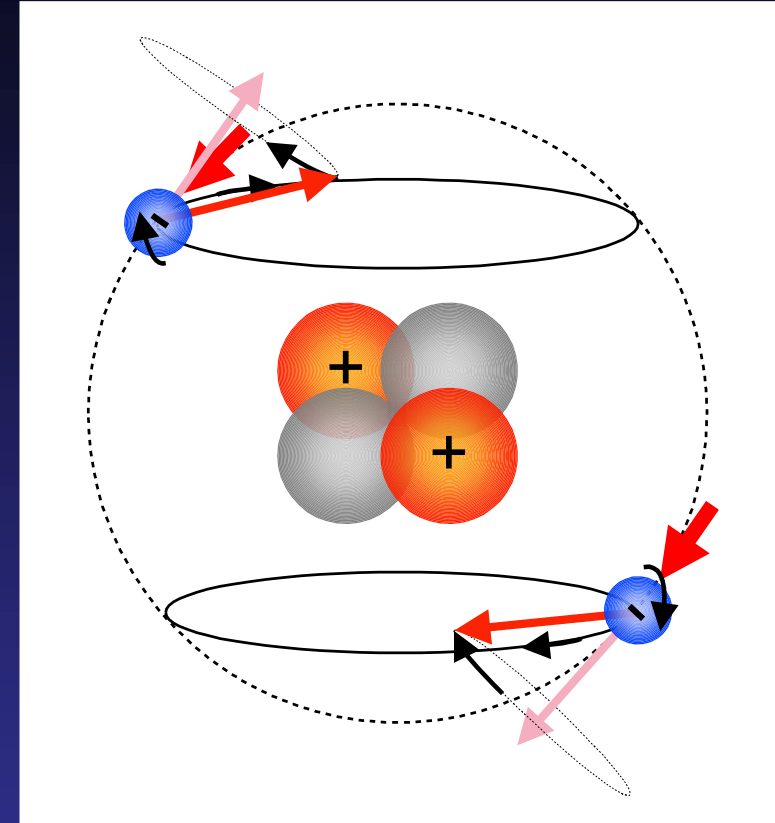
- But decades of experimentation indicate that the 2 electrons have equal and opposite spin angular momentum which is necessary for the gravity theory to work.
- Why is the g-factor for orbital electron's precession frequency approximately 2 and not 1 ?
- Is it because approximately $\frac{1}{2}$ the electron's energy is both radiated to and absorbed from all other radiating electrons in the universe?
- Is it because $\frac{1}{2}$ of its spin angular momentum is from electron spin and $\frac{1}{2}$ is from electron precession?
- **There are many challenges to explaining an atom in a classical way.**





Rewind to slide 7

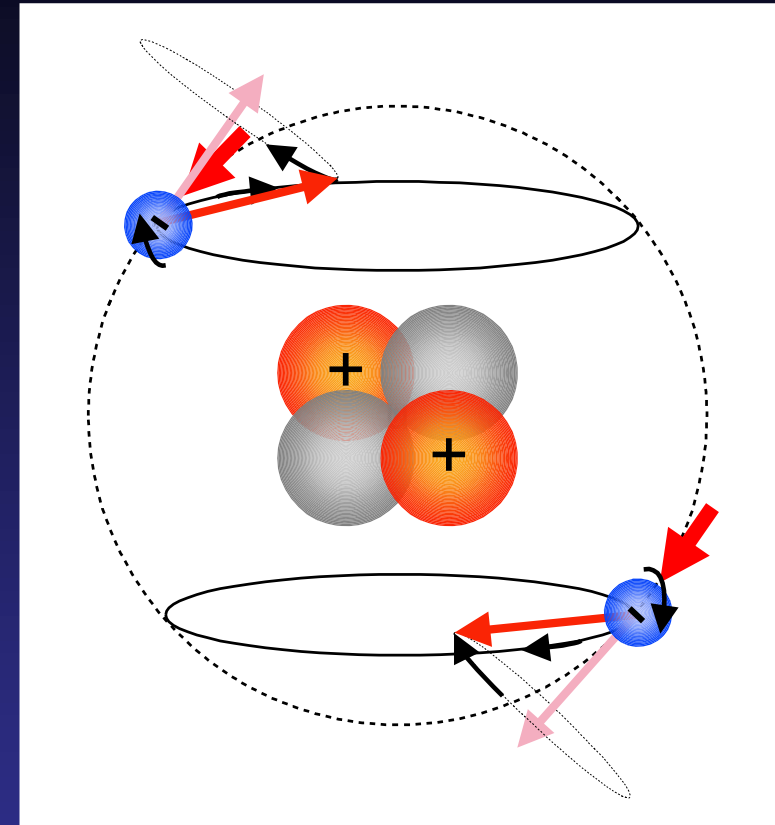
- I wrongly assumed that the two electrons would have to share the same plane even as that plane could be in any orientation in the 1s orbital.
- But maybe they could be in two parallel planes above and below the nucleus.
- They could both have a spin or precession axis tilt to be in opposite orientations and,
- If they both orbit the same direction but in 2 parallel planes, this would be equivalent to having an orbital precession. Is this expected?
- If their tilted spin axes each make one complete precessional rotation per complete orbit, does this also correlates with [De Broglie's matter wave theory](#) of only one complete wave for the 1s orbital?





Rewind to slide 7 *continued*

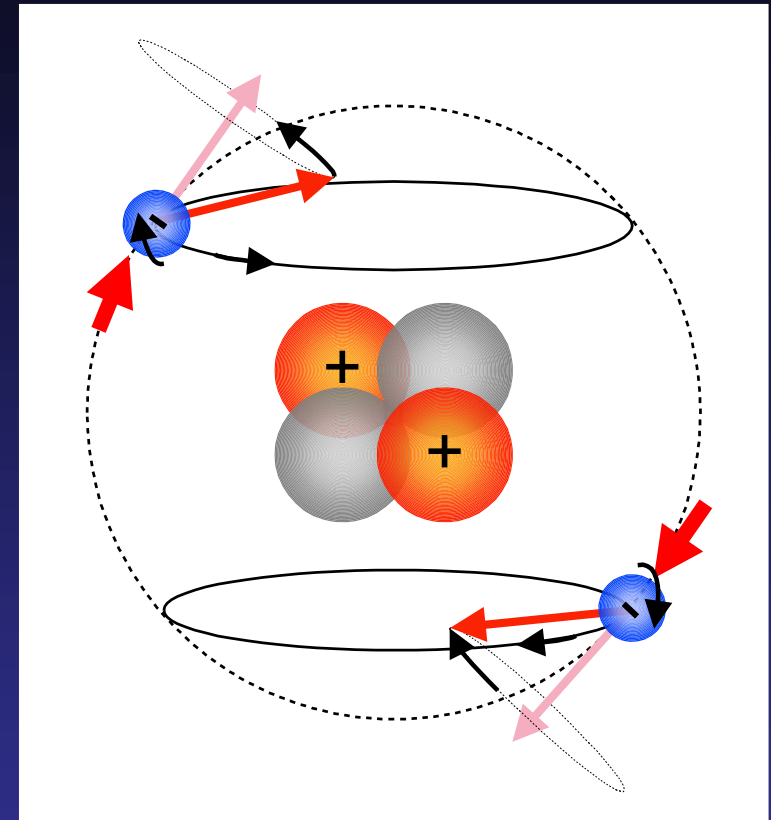
- But this does not work well because, even though the classical electron spins are in opposite directions, each electron's precession is still in the same direction so their individual precessional angular momentums can't cancel each other out.
- That should cause them to emit RF at the electron spin precession frequency.
- Does this match experimental evidence and does it match what quantum theory predicts.





Rewind to slide 7, take 2

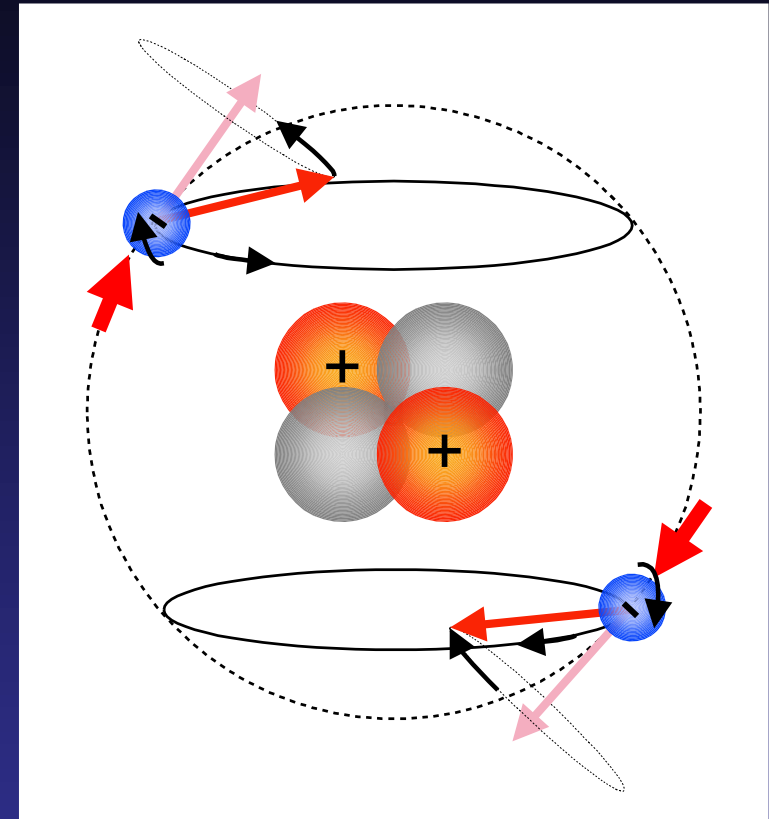
- But if each electron's orbit is in the opposite direction of the other, it causes each electron's spin angular momentum and each electron's precessional angular momentum to all cancel out. **Do experiments verify?**
- However now, the total orbital angular momentum cancels out also but **does this match experimental evidence?**
- This matches what is necessary for the gravity theory to work.
- This also allows the lowest energy state for both electrons as both are **aligned with** their apparent magnetic fields from the nucleus.
- If there is just one complete electron precession per orbital revolution, does this also correlates with De Broglie's matter wave theory of only one complete wave for the 1s orbital?





Rewind to slide 7, take 2 *continued*

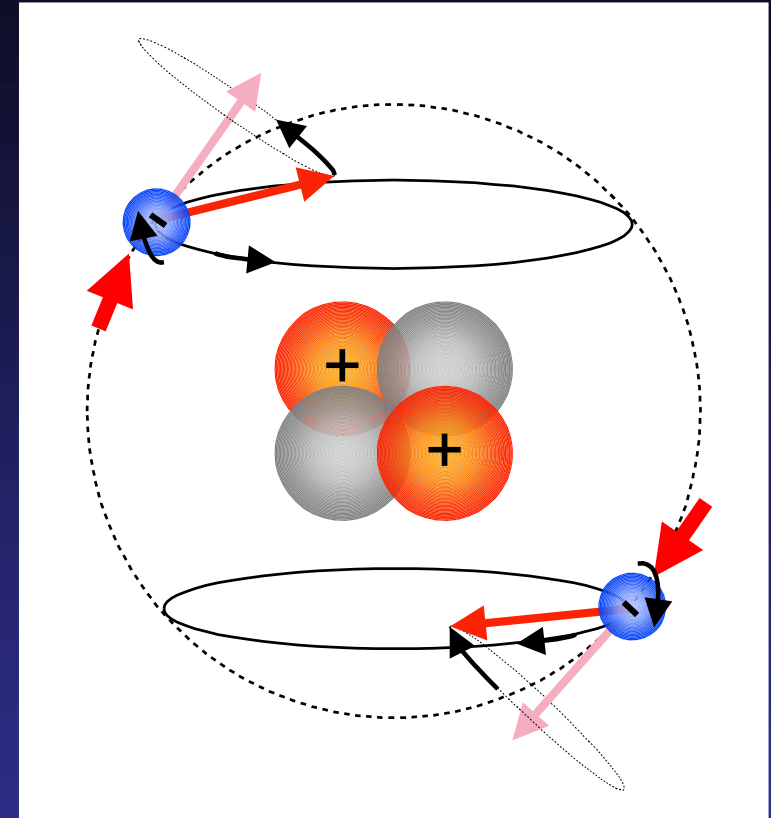
- One draw back to this configuration is that twice per orbit of each, the 2 electrons will get closer and then farther apart from each other so???,
- The electrostatic forces between them might affect their orbital motions a little, possibly causing RF emissions with peaks twice per completed orbit. ;~(
- For this configuration to work, this 2x RF energy lost would have to be regained from the sea of standing waves.
- Do experiments show that after the spin angular momentums cancel, there is still an orbital angular momentum with an orbital magnetic moment that does not cancel? Or,
- Does this happen only in high external magnetic fields that flip an orbit direction so they both orbit the same way, more like slide 7 or 12?





Rewind to slide 7, take 2 *continued*

- This configuration is close but less than 100% satisfying.



- Starting over on next slide by trying to correlate all classical configurations for helium orbital electrons per the four quantum numbers for electrons in atoms.



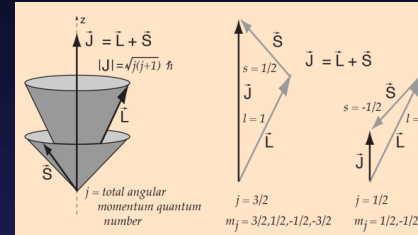
Still Attempting to Correlate Quantum and Classical Orbital Electrons

- The angular momentum vectors; S, L and J relate to orbital electrons.

J = electron total angular momentum

S = electron spin angular momentum

L = electron orbital angular momentum



Regarding the electron spin angular momentum S; in quantum physics, the angular momentum of the classical spin and the angular momentum of classical spin axis precession have both been combined to be the electron spin angular momentum. But in quantum theory, the classical precession axis is now called the spin axis.

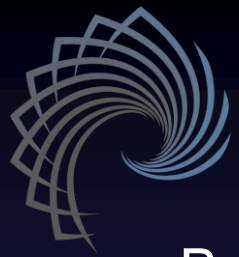
- Just a few reminders to myself:

- The variable “L” is used above specifically for electron orbital angular momentum, but “L” is also used below for general angular momentum.
- A **momentum** vector “p” describes how much mass m (or energy) is moving, multiplied by v, the velocity vector (speed and direction). So, $\mathbf{p} = \mathbf{m} * \mathbf{v}$
- Angular momentum “L” describes momentum around a curve, where r is a vector for distance and direction from the center of rotation and p is momentum. So, $\mathbf{L} = \mathbf{r} \times \mathbf{p}$, where “x” represents a cross product. A cross product is the product of the magnitudes of two vectors and the sine of the angle between them. It is a vector quantity, which means it has both magnitude and direction.
- A **moment** vector designates a magnitude and direction at a “moment” in time.



Still Attempting to Correlate Quantum and Classical Orbital Electrons *continued*

- The four quantum numbers for electrons in atoms are:
 1. The **Principal quantum number (n)** determines the energy level of the orbital electron, and by its relation to the azimuthal quantum number (l), it affects the shape of the orbital that the electron occupies. The principal quantum number can have any positive integer value, $n = 1, 2, 3, \dots$
This appears to possibly correlate to the number of completed precessional rotations of an electron per a single completed orbit. The higher the value of n, the farther the electron is from the nucleus and the higher the energy level of the electron.
 2. The **Azimuthal quantum number (l)** describes the shape of an electron orbital. The value of l can range from 0 to $n-1$, where n is the principal quantum number. The shape of the orbital is determined by the value of l. For example, an $l=0$ orbital is a spherically symmetric s orbital (**not to be confused with “s” for the electron spin quantum number**), an $l=1$ orbital is a dumbbell-shaped p orbital, and an $l=2$ orbital is a cloverleaf-shaped d orbital. **“l” relates to the electron’s orbital angular momentum “L” by equation: $L = \sqrt{l(l+1)}\hbar$, with Planck's constant $\hbar = h/2\pi$.**
 3. The **Magnetic quantum number (m or m_l)** sets the orientation of the electron’s orbital shape relative other orbitals of the same shape. It can have values from $-l$ to l , where l is the azimuthal quantum number. The higher the value of l, the more orientations there are.
 4. The **Electron spin quantum number (s or m_s)** determines the electron’s spin orientation relative to its paired electron or relative to an external magnetic field. It can have two possible values: $+1/2$ or $-1/2$ (UP spin or DOWN spin) **“s” relates to its spin angular momentum “S” by the equation: $|S| = \sqrt{s(s+1)}\hbar$.** Where \hbar is the reduced Planck constant, $h/2\pi$. If s is $-1/2$, then S vectorially subtracts from a positive value of orbital angular momentum L.



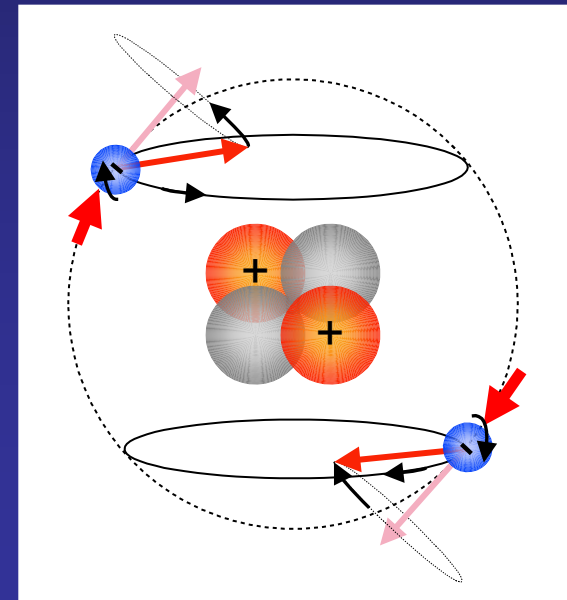
Still Attempting to Correlate Quantum and Classical Orbital Electrons *continued*

- But!:
5. There is also a total angular momentum quantum number denoted as " j " and it is determined by the combination of the orbital angular momentum quantum number " l " and the spin angular momentum quantum number " s ." The value of j can range from $|l - s|$ to $|l + s|$ in integer values. The value of j determines various properties of atoms and molecules, including their energy levels and spectral lines. In addition, j plays a crucial role in determining the magnetic properties of materials.



Still Attempting to Correlate Quantum and Classical Orbital Electrons *continued*

- All possible combinations of quantum numbers for an isolated helium atom are:
 1. $n=1, l=0, m_l=0, s=+1/2$ and $n=1, l=0, m_l=0, s=-1/2$ ($l=0$ indicates the s_1 orbital)
 2. $n=1, l=1, m_l=-1, s=+1/2$ and $n=1, l=1, m_l=-1, s=-1/2$
 3. $n=1, l=1, m_l=0, s=+1/2$ and $n=1, l=1, m_l=0, s=-1/2$
 4. $n=1, l=1, m_l=+1, s=+1/2$ and $n=1, l=1, m_l=+1, s=-1/2$
- First, analyzing ($n=1, l=0, m_l=0, s=+1/2$ and $n=1, l=0, m_l=0, s=-1/2$)
 - The two electrons share the $1s$ orbital and will always have zero total angular momentum.
 - This also indicates that classically, the 2 electrons must have compensating orbital motions.
 - I'm not sure about this example. Orbital angular momentum doesn't seem fully compensated when not in the same plane.
 - In this classical example, the precessional phases are such that their classical spin axes both point inward when the 2 electrons are farthest apart.
 - But in the real world, the precessional phases might be where their classical spin axes both point inward when the 2 electrons are closest together.
 - The 2 electrons should naturally seek the precessional phases that cause the lowest amount of change in mutual repulsion from electrostatic and magnetic interaction as they get close.





Still Attempting to Correlate Quantum and Classical Orbital Electrons *continued*

- The quantum numbers n , l and m_l are related by the equation:

$$n = (2l + 1) + m_l$$

- So, can “ n ” represent the number of complete precessional rotations an electron will have for each completed orbit and could this number of completed precessional rotations occur within the orbital shapes specified by “ l ” and in the relative orbital orientations specified by m_l ?
- The de Broglie wavelength of these electrons can be calculated using their momentum, which is related to their energy levels but, if two different electrons have the same momentum, they will have the same de Broglie wavelength, even though they could be in different orbitals with different principal quantum numbers (n).
- So, could they precess faster or slower in both time and space such that the ratio of space traversed to the duration in time traversed remain c , the velocity of light?
- If they could, could the number of precessions match the De Broglie wavelengths or the principal quantum number?
- The wave function of an orbital electron is: $\Psi(n, l, m, s) = R(n, l, r)Y(l, m, \theta)\chi(s)$, where Ψ is the wave function of the electron, R is the radial wave function, Y is the spherical harmonic function, and χ is the spin function.
- The wave function $\Psi(n, l, m, s)$ for an orbital electron is a solution to the Schrödinger equation for an orbital electron.



Notes to myself: The wave function of an orbital electron:

The Schrödinger equation describes the time-evolution of an orbital electron. It is a partial differential equation that relates the wave function of the orbital electron to its energy. The equation is written as: $i\hbar\partial\Psi/\partial t = H\Psi$, where:

- i is the imaginary unit, a complex number that is defined as the square root of -1.
Why is the imaginary unit used as part of representing the wave nature of matter?
See next slide.
- \hbar is the reduced Planck constant
- ∂ is used to represent a partial derivative, i.e., a function with respect to one variable, while holding the other variables constant. For example, if $f(x, y)$ is a function of two variables, then $\partial f/\partial x$ is the partial derivative of f with respect to x
- Ψ is the wave function and is a complex-valued function of position and time and the square of the wave function, $|\Psi|^2$, gives the probability of finding the particle at a particular point in space at a particular time.
- t is time
- H is the Hamiltonian operator, which describes the energy of the quantum system. The Hamiltonian operator is typically written as: $H = T + V$, where:
 - T is the kinetic energy operator, and $T = -\hbar^2/2m \nabla^2$, where:
 - » \hbar is the reduced Planck constant
 - » m is the mass of the particle
 - » ∇^2 is the Laplacian operator
 - V is the potential energy operator, and $V = -k_e/r$, where:
 - » k_e is the Coulomb constant
 - » r is the distance between the electron and the nucleus



Notes to myself: The wave function of an orbital electron: *continued*

- Why is the imaginary unit used as part of representing the probability wave nature of finding matter in a particular time and place?
 - The wave function needs both real and imaginary parts for the math results to match real world observations.
 - The real part represents the amplitude of the probability wave.
 - The imaginary component represents phase or position in space relative to a chosen reference point, typically the positive real axis.
 - In electronics, the characteristics of space itself, specifically, coefficients of capacitive permittivity and inductive permeability are what causes the imaginary component of the math that describes the phase of electrical signals, but in quantum mechanics, what is it that causes the imaginary component of the wave function? In quantum mechanics, the imaginary component represents a phase factor that determines how the wave function evolves over time. OK, but what causes this imaginary component?
- Are there classical processes taking place in 3D space and 3D time that explain the imaginary component and that allow the probability wave function results to match real world observations? Ref: [The Nature of Time](#)

Note: In the following slides about the phase angle of precessing orbital electrons, and specifically when the phase angle is an integer multiple of π , I'm contending there are real electromagnetic interactions pushing electrons into these precessional phases where interactions are in greatest harmony.



Notes to myself: The wave function of an orbital electron: *continued*

- The magnetic moment of an orbital electron is proportional to its precessional frequency and to the imaginary part of its wave function.
- So, an orbital electron's precessional frequency is also proportional to the imaginary part of its wave function.
- Relation of electron precessional phase to precessional frequency:

$$\phi = \omega t$$

where:

ϕ is the precessional phase in radians

ω is the precessional frequency in radians per second

t is the time in seconds

- What is the relation between an orbital electron's precessional phase and the imaginary part of its wave function? *Does everyone else know this already?*
- From past research: *When an electron's spin is flipped, like UP to DOWN then UP again, its precessional phase shifts 180 degrees. It must do 2 more spin flips to get back to the same precessional phase.*



Notes to myself: The wave function of an orbital electron: *continued*

- With an isolated electron in a vacuum, not in a magnetic material, when its spin is flipped, like UP to DOWN then UP again, is it correct that its precessional phase shifts 180 degrees and the interference pattern in 2 slit experiments is different and it must undergo 2 more spin flips for its precessional phase to be the same as it originally was?
- **According to iask.ai:** According to quantum mechanics, an isolated electron in a vacuum has a property called spin, which is a measure of its intrinsic angular momentum. When the spin of an electron is flipped, for example from UP to DOWN and then back to UP again, its precessional phase shifts by 180 degrees. This means that the interference pattern in a two-slit experiment will be different than it would have been if the spin had not been flipped. In order for the precessional phase to return to its original state, the electron must undergo two more spin flips.
- This phenomenon is known as spin precession and is caused by the interaction between the magnetic moment of the electron and any external magnetic fields present. In a vacuum, there may not be any external magnetic fields, but the electron still has an intrinsic magnetic moment due to its spin.
- It should be noted that this description assumes that the electron is truly isolated and not interacting with any other particles or fields. In reality, it is extremely difficult if not impossible to completely isolate an electron in a vacuum.
- In summary, when the spin of an isolated electron in a vacuum is flipped, its precessional phase shifts by 180 degrees and it must undergo two more spin flips to return to its original state.
- AI did pretty well with this answer except the isolated electron is really still having classical spin interactions due to all the classically radiated and absorbed electromagnetic energy with all other electrons in the universe.



Notes to myself: The wave function of an orbital electron: *continued*

- Is it true that even isolated electrons will have precessional motion all the time and that the precessional phase of this motion will shift 180° when the electron is flipped from spin up to down and then up again?
- **According to iask.ai:** Yes, it is true that even isolated electrons will have precessional motion all the time. This is due to the intrinsic property of electrons called spin, which is a quantum mechanical property that describes the angular momentum of the electron. The spin of an electron can be thought of as a tiny magnetic moment that interacts with external magnetic fields and causes the precessional motion
- The precessional phase of this motion will shift 180° when the electron is flipped from spin up to down and then up again. This is because the direction of the magnetic moment changes when the spin flips, causing the precession to change direction as well.
- The precessional motion of electrons has important implications in various fields such as quantum computing, magnetic resonance imaging (MRI), and spintronics. Understanding and controlling the precessional motion of electrons is crucial for developing new technologies based on these principles.
- In conclusion, isolated electrons do exhibit precessional motion due to their intrinsic spin property, and the precessional phase does shift 180° when the spin is flipped.



Notes to myself: The wave function of an orbital electron: *continued*

- When you said: "In conclusion, isolated electrons do exhibit precessional motion due to their intrinsic spin property, and the precessional phase does shift 180° when the spin is flipped." is it not more correct that when the axis of precession of an isolated electron spin is flipped two times then its precessional phase shifts by a 180 degrees?
- **According to iask.ai:** Yes, you are correct. When the axis of precession of an isolated electron spin is flipped two times, then its precessional phase shifts by 180 degrees. This is due to the fact that the intrinsic spin property of electrons causes them to exhibit precessional motion, which is a kind of rotational motion where the axis of rotation itself rotates. When the spin is flipped, the direction of the axis of precession also flips, which causes the precessional phase to shift by 180 degrees.
- This phenomenon has been extensively studied in quantum mechanics and has important implications for a wide range of applications, including magnetic resonance imaging (MRI) and quantum computing. Understanding the behavior of isolated electron spins is crucial for developing new technologies and advancing our understanding of fundamental physics.
- In conclusion, when the axis of precession of an isolated electron spin is flipped two times, its precessional phase shifts by 180 degrees due to its intrinsic spin property.



Notes to myself: The wave function of an orbital electron: *continued*

- Is it not possible that if the precessional motion of even isolated electrons causes them to radiate electromagnetic energy in the classical way that they can still also be absorbing in a classical way just as much electromagnetic energy from all other radiating electrons in the universe?
- **According to iask.ai:** It is indeed possible that the precessional motion of isolated electrons causes them to radiate electromagnetic energy in a classical way, and they can still absorb electromagnetic energy from all other radiating electrons in the universe. This phenomenon is known as electron-electron scattering, and it occurs when two electrons interact through the exchange of virtual photons.
- According to quantum electrodynamics (QED), the theory of how light and matter interact at the quantum level, all particles with an electric charge emit and absorb photons. The emission of photons by electrons is known as radiation, while the absorption of photons is called absorption. In the case of electron-electron scattering, both processes occur simultaneously.
- When two electrons approach each other, they exchange virtual photons that carry energy and momentum. These virtual photons can be thought of as fluctuations in the electromagnetic field that surrounds each electron. As a result of this interaction, the electrons experience a force that changes their trajectory.
- The exchange of virtual photons between electrons also results in a transfer of energy and momentum. This means that one electron can lose energy while the other gains energy, or both electrons can exchange energy in a way that conserves their total energy.
- In summary, it is possible for isolated electrons to radiate electromagnetic energy through precessional motion and still absorb electromagnetic energy from other radiating electrons in the universe through electron-electron scattering.



Notes to myself: The wave function of an orbital electron: *continued*

- In classical physics, since there should be radiated and absorbed electromagnetic energy between orbital electrons' from their orbital and precessional motions wouldn't the absorbed electromagnetic energy apply forces causing all these electron's motions to become more synchronized with each other?
- **According to iask.ai:** In classical physics, the radiated and absorbed electromagnetic energy between orbital electrons from their orbital and precessional motions can indeed cause the electrons' motions to become more synchronized with each other. This phenomenon is known as electron spin relaxation.
- Electron spin relaxation occurs when the magnetic dipole moments of the electrons interact with each other, causing them to exchange energy and align their spins. This alignment reduces the electrons' total magnetic moment and thus lowers the energy of the system. The process can occur through various mechanisms, such as spin-spin interactions, spin-lattice interactions, and spin-orbit interactions.
- One consequence of electron spin relaxation is that it can lead to a phenomenon called spin-lattice relaxation. In this process, the electron spins relax by transferring their excess energy to the lattice vibrations of the material. This transfer of energy causes the lattice to heat up and can be detected as a change in temperature.
- Another consequence of electron spin relaxation is that it can affect the magnetic properties of materials. For example, in magnetic resonance imaging (MRI), the relaxation times of protons in water molecules are used to create images of internal body structures. The relaxation times depend on the local magnetic field, which is affected by nearby electrons.
- Overall, electron spin relaxation is an important phenomenon in classical physics that can have significant effects on materials and their properties.



Notes to myself: The wave function of an orbital electron: *continued*

- ok, but classically, can't this process be taking place all the time among all electrons of all orbitals of all atoms in the universe specifically from their rotational motions as opposed to their rectilinear motions such that they all have a tendency to become more synchronized in their motions and have all classically radiated electromagnetic energy replaced by classically absorbed electromagnetic energy from all other electrons in the universe?
- **According to iask.ai:** According to classical physics, the process of synchronization among all electrons of all orbitals of all atoms in the universe can indeed take place through their rotational motions. This phenomenon is known as collective electron behavior or collective electron oscillation. In this process, electrons in different atoms influence each other's motion by exchanging electromagnetic radiation, leading to a synchronized motion of the entire system of electrons.
- However, it is important to note that classical physics has its limitations and cannot fully explain the behavior of electrons in certain situations. In quantum mechanics, for example, the behavior of electrons is described by wave functions that do not have a definite position or momentum. Therefore, the concept of synchronization among all electrons in the universe may not be applicable in the quantum realm.
- In summary, while classical physics suggests that collective electron behavior can occur through their rotational motions, it is important to consider the limitations of this theory and explore other explanations from different fields such as quantum mechanics.
- **I disagree with AI's 2nd paragraph. I think it is just repeating what quantum physicists say without fully calculating it all out for itself.**



Notes to myself: The wave function of an orbital electron: *continued*

- Previously you said: "the process of synchronization among all electrons of all orbitals of all atoms in the universe can indeed take place through their rotational motions. This phenomenon is known as collective electron behavior or collective electron oscillation. In this process, electrons in different atoms influence each other's motion by exchanging electromagnetic radiation, leading to a synchronized motion of the entire system of electrons." but isn't collective electron oscillation only applicable to certain materials or plasmas?
- **According to iask.ai:** Yes, you are correct. Collective electron oscillation or plasma oscillation is a phenomenon that is observed in plasmas, which are ionized gases consisting of free electrons and positive ions. In such systems, the collective behavior of electrons can lead to the formation of waves that propagate through the plasma. These waves are known as plasma waves or electrostatic waves and are characterized by their frequency and wavelength.
- Plasma oscillations are important in many areas of physics and engineering, including plasma physics, materials science, and semiconductor device fabrication. They play a crucial role in phenomena such as plasma heating and confinement, laser-plasma interactions, and the operation of plasma-based devices such as particle accelerators.
- However, it should be noted that collective electron behavior is not limited to plasmas alone. In fact, it is a fundamental concept in condensed matter physics, where it underlies many important phenomena such as superconductivity and magnetism. In condensed matter systems such as metals and semiconductors, the collective behavior of electrons can lead to the formation of quasiparticles such as phonons and magnons, which behave like particles with an effective mass.
- In summary, while collective electron behavior or oscillation is most commonly observed in plasmas, it is a fundamental concept in physics that has broad applications across many fields.



Notes to myself: The wave function of an orbital electron: *continued*

- Regarding the wave function of an orbital electron, does the phase of the imaginary component of the wave function mean exactly the same thing as the phase of the electron's precessional motion?
- **According to iask.ai:** The phase of the imaginary component of the wave function does not mean exactly the same thing as the phase of the electron's precessional motion. The wave function of an orbital electron is a mathematical function that describes the probability density of finding an electron in a particular location around an atom's nucleus. The wave function is a complex function that has both real and imaginary components, and the phase of each component determines the interference pattern that results from the superposition of multiple waves.
- In contrast, precessional motion refers to the motion of a spinning object around an axis that itself is also in motion. In the context of electrons in atoms, precession generally refers to the motion of an electron's spin around a magnetic field. The phase of this motion is related to the orientation of the electron's magnetic moment with respect to the magnetic field.
- While both wave functions and precessional motion involve phases, they are fundamentally different phenomena that describe different aspects of an electron's behavior. The wave function describes the probability density of finding an electron in space, while precessional motion describes the way in which an electron's spin interacts with a magnetic field.



Notes to myself: The wave function of an orbital electron: *continued*

- If the magnetic moment of an orbital electron is proportional to its precessional frequency and to the imaginary part of the electron's wave function and if the precessional phase is related to the precession frequency by the equation: $\phi = \omega t$, then what equation expresses the relation between the electron's precessional phase and the imaginary part of the electron's wave function? **According to iask.ai:**
- The relation between the electron's precessional phase and the imaginary part of its wave function can be expressed by the equation: $\text{Im}(\Psi) = \text{Im}(\Psi_0) * \exp(i\phi)$ where,
 - $\text{Im}(\Psi)$ is the imaginary part of the electron's wave function,
 - $\text{Im}(\Psi_0)$ is the initial value of the imaginary part of the wave function,
 - ϕ is the electron's precessional phase, and i is the imaginary unit.
- **This equation shows that the imaginary part of the electron's wave function varies with its precessional phase and that this variation can be described by a complex exponential function.**
- The precessional phase ϕ is related to the precession frequency ω by the equation $\phi = \omega t$, where t is time.
- Therefore, we can write: $\text{Im}(\Psi) = \text{Im}(\Psi_0) * \exp(i\omega t)$
- This equation shows that the imaginary part of the electron's wave function oscillates with time at a frequency proportional to its magnetic moment. The amplitude and phase of this oscillation depend on the initial value of the imaginary part of the wave function and the precessional phase of the electron.
- In summary, the relation between the electron's precessional phase and the imaginary part of its wave function can be described by a complex exponential function that depends on time and initial conditions.



Notes to myself: The wave function of an orbital electron: *continued*

- In the equation: $\text{Im}(\Psi) = \text{Im}(\Psi_0) * \exp(i\phi)$, at what phase angles is the imaginary component zero?
- **According to iask.ai:** In the given equation: $\text{Im}(\Psi) = \text{Im}(\Psi_0) * \exp(i\phi)$, the imaginary component will be zero at phase angles that are integer multiples of π .
- This is because when ϕ is an integer multiple of π , the exponential term becomes either 1 or -1, depending on whether ϕ is an even or odd multiple of π . In either case, the imaginary component of the equation becomes zero. Therefore, the equation reduces to: $\text{Im}(\Psi) = 0$, which means that the wave function Ψ has no imaginary component at these phase angles.
- When the imaginary component is zero, i.e., $\text{Im}(\Psi) = 0$, this implies that the wave function Ψ has no imaginary part and is purely real.
- **When the imaginary component is zero it means that the wave function represents a state that has a definite value of energy and momentum, and it can be measured with certainty.**
- In other words, the state is in a stationary state.
- To find at what phase angles the imaginary component is zero, we can substitute $\text{Im}(\Psi) = 0$ in the given equation:
$$\text{Im}(\Psi) = \text{Im}(\Psi_0) * \exp(i\phi)$$
$$0 = \text{Im}(\Psi_0) * \exp(i\phi)$$
- As $\exp(i\phi)$ is a complex exponential function, it can be written as: $\exp(i\phi) = \cos(\phi) + i \sin(\phi)$
- Substituting this in the above equation, we get:
$$0 = \text{Im}(\Psi_0) * (\cos(\phi) + i \sin(\phi))$$
- For the imaginary component to be zero, $\sin(\phi)$ must be equal to zero. This occurs when ϕ is an integer multiple of π , i.e., $\phi = n\pi$ where n is an integer.



Notes to myself: The wave function of an orbital electron: *continued*

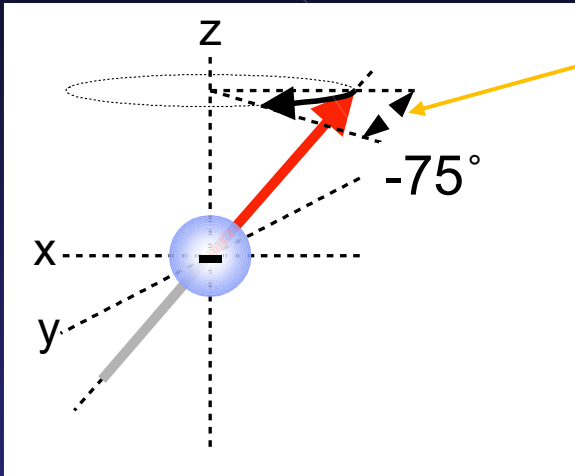
- According to iask.ai:
 - When an orbital electron is in an eigenstate of the Hamiltonian operator, it means that the electron has a specific energy and wavefunction. The wavefunction describes the probability distribution of finding the electron at a particular location around the nucleus. **Therefore, when an electron is in an eigenstate, it is not just anywhere around the nucleus but rather in a specific orbital.**
 - An orbital is a region of space around the nucleus where there is a high probability of finding an electron. Each orbital can hold a maximum of two electrons with opposite spins. The energy of an electron in an orbital is determined by its quantum number, which also determines the shape and orientation of the orbital.
 - The Hamiltonian operator represents the total energy of a system, including kinetic and potential energies. When an electron is in an eigenstate of the Hamiltonian operator, it means that its energy is well-defined and quantized. The eigenvalue represents the energy of the electron in that state, while the eigenvector represents its wavefunction.
 - In summary, when orbital electrons are in an eigenstate of the Hamiltonian operator, they are in a specific orbital with a well-defined energy and wavefunction.



Notes to myself: The wave function of an orbital electron: *continued*

- In quantum mechanics, the imaginary component of the wave function of an orbital electron represents a phase factor that determines how the wave function evolves over time **but what characteristics of the electron's spin and precession cause this wave function phase factor and when is the phase factor value equal to zero?**
- **According to iask.ai:** In quantum mechanics, the imaginary component of the wave function of an orbital electron represents a phase factor that determines how the wave function evolves over time. **This phase factor is known as the "Berry phase," named after the British physicist Sir Michael Berry, who first described it in 1984.**
- The Berry phase is caused by the spin and precession of the electron. The spin of an electron is a fundamental property that gives rise to a magnetic moment. When an electron is placed in a magnetic field, its spin precesses around the direction of the field. This precession causes a change in the phase of the wave function, which accumulates over time and results in the Berry phase.
- The value of the Berry phase depends on the path taken by the electron in space. If the electron is moved around a closed loop, its wave function will acquire a phase shift that depends only on the area enclosed by the loop. This means that if two different paths are taken around the same area, they will result in the same Berry phase.
- The value of the Berry phase can be zero under certain conditions. For example, if an electron is moved around a loop in a magnetic field that is uniform in space, its wave function will not acquire a phase shift. Similarly, if an electron is moved around a loop in a magnetic field that is perpendicular to its spin axis, its wave function will also not acquire a phase shift.
- In summary, the imaginary component of the wave function of an orbital electron represents a phase factor known as the Berry phase, which is caused by the spin and precession of the electron. The value of this phase factor depends on the path taken by the electron in space and can be zero under certain conditions.

Definitions of rotational terms for electrons, using the usual way of designating these types of rotation, with Euler angles:



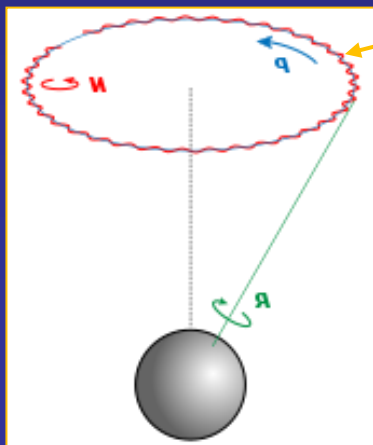
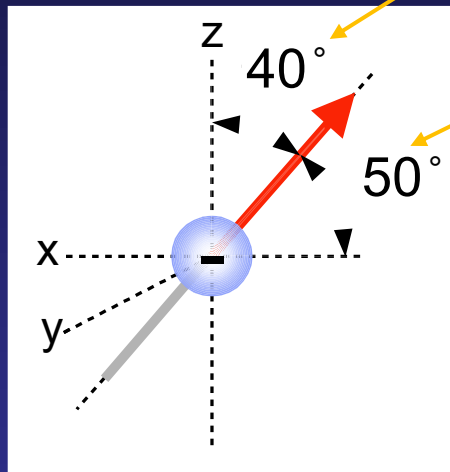
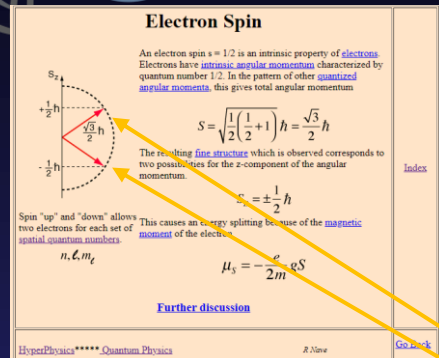
- Electron **Precession Angle** (α or ψ) This is a Euler angle designation that represents the degree of rotation about the precession axis (Z axis), at an instant in time, in this case, using the X axis as a reference for an angle of zero. For an electron, this will continuously change as an electron precesses about a precession axis (Z axis).
- Electron **Precession phase**
 1. (suggested definition in the context of its interaction with all other matter in the universe); the difference angle between the Precession Angle of the electron and the orientation of the magnetic field vector of the EM standing waves at its physical location due to EM interaction with all other electrons in the universe, or
 2. the difference angle between the Precession Angle of the electron versus the orientation of the magnetic field vector of the EM waves at its physical location from an electron spin resonance microwave antenna signal.
- References:

<https://demonstrations.wolfram.com/EulerAnglesPrecessionNutationAndSpin/>
<https://rotations.berkeley.edu/the-euler-angle-parameterization/>
https://en.wikipedia.org/wiki/Euler_angles

From Wikipedia:

“Different authors may use different sets of rotation axes to define Euler angles, or different names for the same angles. Therefore, any discussion employing Euler angles should always be preceded by their definition.”

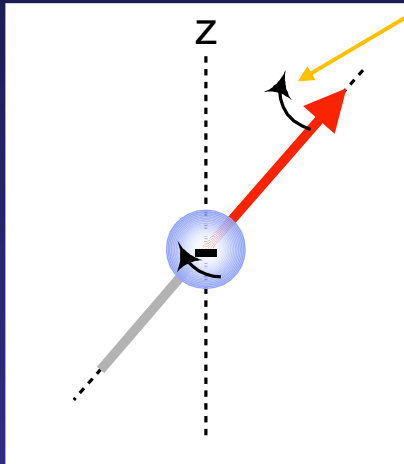
Definitions of rotational terms for electrons, using the usual way of designating these types of rotation, with Euler angles: *continued*



- Electron **Tilt Angle** represents the angle away from the Z axis as it precesses around the Z axis. *Some research papers refer to this as the **precession angle**, but **precession angle** usually refers to something else when using Euler Angle designations.*
- Electron **Nutation Angle** (β or θ) This is a Euler angle designation that represents the instantaneous angle between the electron and the plane normal to the Z axis as it precesses about the Z axis. If the electron has no nutational motion, then this angle will stay the same as the electron precesses about the Z axis. If there is nutational motion, then this nutation angle will oscillate as the electron's precession angle continuously advances.
- Two possible **nutational angles** arise from interaction with the EM sea of standing waves among all electrons.
- Electron **Nutation**: There is the possibility the electron has nutational motion in addition to precessional motion. This might cause EM interaction with nucleon quarks at gamma ray frequencies. This EM interaction would become part of the universal sea of standing waves and create the resistance to movement known as inertia.
- References:

<https://demonstrations.wolfram.com/EulerAnglesPrecessionNutationAndSpin/>
<https://rotations.berkeley.edu/the-euler-angle-parameterization/>
https://en.wikipedia.org/wiki/Euler_angles

Definitions of rotational terms for electrons, using the usual way of designating these types of rotation, with Euler angles: *continued*



- Electron **Spin Angle** (γ or ϕ) This is a Euler angle designation that represents the degree of rotation about the classical spin axis. This angle might not matter much since the electron's shape and features are presumed to be symmetrical and indistinguishable about the axis of classical spin.
- It matters mostly in that the change in its **Spin Angle** over time represents its rate of classical rotation and this relates to its classical angular momentum.
- But the electron is likely a vortex of some kind and not a solid object. This diagram is symbolic only.
- I don't know how to show a zero-reference angle to measure the **Spin Angle** relative to, since this angle does not start on any of the 3 primary axes, X, Y or Z. Maybe think of the zero degrees of **Spin Angle** direction as coming out of the screen

References:

<https://demonstrations.wolfram.com/EulerAnglesPrecessionNutationAndSpin/>

<https://rotations.berkeley.edu/the-euler-angle-parameterization/>

https://en.wikipedia.org/wiki/Euler_angles



Initial presumptions and required variables while modeling motions of magnetic vectors of electrons

1. The length of red arrows indicates the strength of the magnetic field.
2. Part of the length is from the contribution from electron spin and part is from orbital motion.
3. When modeling an array of spins, the total maximum red arrow length should be just short enough that arrows don't touch arrows of adjacent spins.
4. When modeling combined magnetic fields of precessing paired electrons, after the UP and DOWN magnetic vectors of each electron cancel out, the precessing portions do not always cancel. That will leave the summation arrows toggling direction but without rotating anymore since the counter-rotations cancel.
5. In arrays of spins, the direction of arrows, needs option to change back and forth for adjacent atoms, same direction or opposite direction.
6. The electron orbital precession angle needs to be adjustable.
7. The electron spin precession angle needs to be adjustable.
8. The initial electron orbital precessional phase needs to be adjustable.
9. The initial electron spin precessional phase needs to be adjustable.
10. The initial electron orbital precessional frequency needs to be adjustable.
11. The initial electron spin precessional frequency needs to be adjustable.
12. Amplitude of spinwave variations solely in the electron spin precession.
13. Frequency of spinwave variations solely in the electron spin precession.
14. Direction of spinwave variations solely in the electron spin precession.
15. Amplitude of spinwave variations solely in the electron orbital precession.
16. Frequency of spinwave variations solely in the electron orbital precession.
17. Direction of spinwave variations solely in the electron orbital precession.
18. Need an option to create the spinwaves either by adjusting the initial precession phase of each spin or by momentarily increasing then decreasing the precession frequency?