Energy Path Theory: Helical Structure and the Conversion of Photon Momentum into Mass

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Abstract

Energy Path Theory proposes that mass is not a fundamental property but emerges from the centripetal force produced when a photon is confined into a helical energy path. A photon folding onto itself forms two opposite-phase helices corresponding to the electron and positron. The required centripetal force—generated by the vacuum electric field—stabilizes the helical motion and defines the particle's effective mass. This geometric mechanism naturally explains spin-½, the electron's nonzero minimum motion, Lorentz behavior, and the mass hierarchy of leptons.

This study proposes a model aimed at explaining the formation of electron mass and the mechanisms by which energy is converted into mass. The theory is developed on the basis that photons propagate along energy paths in spacetime while bending into a helical configuration, and that the centrifugal forces generated by these curvatures contribute to mass acquisition. In this framework, the direct conversion of photon momentum into mass is explained in a manner that remains consistent with both classical and modern physics.

To understand the annihilation of the most fundamental massive particles—such as electrons and positrons—through thought experiments, a model is considered in which oppositely charged masses can convert each other's mass into energy waves. When photons are modeled as oscillations on a one-dimensional energy paths, the curvature of the energy path represents massive particles, and the annihilation of opposite curvatures explains the disappearance of matter. A simple example is a long garden hose with multiple bends in opposite directions: when the hose is pulled taut, the bends annihilate each other and straighten out.

If spacetime contains one-dimensional energy paths and photons represent oscillations on these paths, then curved energy paths form a helical structure. When a photon wave closes upon itself, two symmetry-related, oppositely phased helices are formed—one corresponding to the electron and the other to the positron. The helical length of the electron increases as it accelerates, yet it can never become perfectly straight; for this reason the electron can never reach the speed of light. Conversely, when the helix is compressed, its length shortens, but it cannot collapse into a circular structure; this indicates that the electron can never be at rest and must always remain in motion.

The electron's spin can then be naturally explained through the geometric and dynamical properties of the helix. As the helical arc moves along the Z-axis, it appears to rotate when observed from the X or Y direction. When an ordinary coil is accelerated, its observed rotation rate appears to increase. A longer helix appears to rotate more slowly; however, if the helix elongates during acceleration, the observed rotation rate remains constant. This mechanism naturally explains why the intrinsic angular momentum (spin) of the electron remains constant regardless of changes in velocity or energy.

Within the Energy Path Theory, angular momentum is calculated before mass is defined; thus, spin must be derived from photon momentum. A photon oscillates in space as a two-dimensional wave, with its propagation direction and spin axis aligned, giving it spin 1. However, when a photon folds onto itself to form symmetry-related helical energy paths (the electron–positron pair), the direction of the electron's motion no longer coincides with the photon's propagation direction. A 360° rotation along the helix corresponds to a 180° rotation in its circular component, and the helix completes a full rotation only after four cycles—i.e., 720°—at which point the spinor becomes identical again. The spinor rule (double-valued representation) and the SU(2) topological transformation arise precisely from this structure.

$k = wavenumber = \frac{2\pi}{\lambda}$

$r = the\ helix's\ reduced\ compton\ wavelength\ = \frac{\lambda}{4\pi}$ $kxr = \frac{1}{2}$ as the energy increases, k increases while r decreases, so the product $kxr\ remains\ equal\ to\ \frac{1}{2}\ at\ all\ times.$

$$p = \frac{E}{c} \quad E = \hbar xcxk \quad S = \frac{E}{c}xr \quad S = \frac{\hbar xcxkxr}{c} = \hbar xkxr = \frac{\hbar}{2}$$

The electron can never adopt a purely circular configuration as long as it moves; it always retains its helical form (requiring 720° for identity), and therefore its spin is perpetually ½.

When the electron is interpreted not as a pointlike billiard-ball particle but as a tension or curvature along an energy path, its position uncertainty and measurement dependence gain physical meaning. Consider a long rope under tension: where one grasps the rope does not change the feel of the tension or oscillation—the rope responds identically at all points. Similarly, the helical curvature of the electron along the energy path appears wherever the measurement occurs; its influence can be felt along the entire path. This explains why an electron appears "localized" at the point of measurement, and why its behavior depends on the act of measurement.

The helical structure—through the orientation of its tangent vectors—determines the direction of photon propagation, and its rotational and elongation dynamics ensure compatibility with Lorentz contraction in electromagnetic fields. Each tangent vector of the helix corresponds to a light wave propagating in its own direction, and a helix contains infinitely many such tangents. Consequently, the electron appears as a cloud of light and possesses inherent position uncertainty. Because the electron's position depends on its direction of motion, any interference—such as measurement—selects an energy path according to its motion and localizes the electron at the point of measurement.

A fast electron has an elongated helix structure; therefore, its tangent vectors become more aligned with its direction of motion, reducing position uncertainty. However, since its virtual photons tend to share nearly the same direction of propagation and because the helix elongates due to Lorentz dynamics, the electron's structure becomes more photon-like as it accelerates, increasing momentum uncertainty.

A photon possesses electric and magnetic field planes perpendicular to its direction of propagation. Since each tangent vector of the electron's helical structure corresponds to a photon, the ensemble of electric and magnetic planes constitutes the electron's electromagnetic field, which contracts according to Lorentz contraction depending on the tangent vectors (i.e., velocity). When examining the electron's helical structure, considering not just a single tangent vector but a larger cross-section reveals that helices of different orientations, phases, and velocities can form. This effect depends on which portion of the helix is observed along the electron's path, thereby giving rise to "virtual" photons and electron–positron pairs within the electron's interior.

If a photon is a wave on a one-dimensional energy path and the path assumes a helical configuration, then photon momentum must generate a centripetal force. Light normally has no rest mass, yet it possesses momentum defined by

$$P = E/c$$

When the photon begins rotating in a helix, its tangent vectors always propagate at the speed of light c. In this case, the system behaves analogously to classical circular motion. For circular or helical systems, the centripetal force is given by:

$$F = mv^2/r$$

Since mass is not yet defined, the same concept can be expressed in terms of momentum:

$F = pv/r$ Because the speed of light is always c, we obtain:

This expression determines the force required for a helical structure of a given radius to rotate, based on its energy. The effective mass gained by the helical system is then defined by the relationship between energy and centripetal force:

$$F = \frac{pc}{r}$$

$$m = Fr/c^2$$

This expression is directly compatible with Einstein's relationship $E = mc^2$, but here mass emerges explicitly from the system's dynamics—specifically, from the product of force and radius.

To determine the physical origin of mass, the physical counterpart of the centripetal force F is associated with the vacuum's electric field threshold. According to quantum electrodynamics, the vacuum electric field strength (Schwinger limit) is

$E_{vacuum} = 1.32 \times 10^{18}\ V/m$

The effect of this field on an electron with charge e generates a force of magnitude:

$(e = 1.602 \times 10 - {}^{19}C)$

$F = E_{vacuum}\ x\ e = \ 0.212\ N$

The radius of the electron's helical structure at rest is taken as the reduced Compton radius:

r_e=$3.86x10^{-13}m$

Using these values in the mass formula gives

$m = \frac{0.212x(3.86x10^{-13})}{(3x10^{8})^2} = 9.1x10^{-31}$

which matches the experimentally measured electron mass precisely. Thus, using only classical force and energy relationships—without invoking any quantum assumptions—the electron mass is correctly reproduced.

Considering the same system under different electric field strengths yields the other members of the lepton family. The general formula is:

$$m = \frac{(E_{local}\ x\ e)x\ r}{c^2}$$

where E represents the local electric field strength at which the particle forms. Inverting this relation yields:

$$E_{local} = \frac{mc^2}{e.r}$$

indicating that different leptons emerge from different field strengths. While many models assume that the Compton radius scales inversely with mass, this centripetal-force-based model demonstrates that the Compton radius does not physically scale with mass; rather, the same geometric interaction radius applies to all leptons. This approach is consistent with experimental and theoretical limits on electric field strengths.

In this model, mass is defined by:

$$m = \frac{(E_{local}\ x\ e)x\ r}{c^2}$$

where F is the force generated by the electric field acting on the lepton's charge, and r is the lever arm (effective radius). Solving for E yields:

$$E_{local} = \frac{mc^2}{e.r}$$

If r is taken as the particle's own Compton radius $r = \frac{\hbar}{m.c}$, the resulting electric field strengths exceed known physical limits by several orders of magnitude. However, if r is taken to be the electron's Compton radius , the resulting field strengths fall within experimentally supported ranges, such as those discussed in heavy-ion collisions and LHC measurements. Thus, the physically correct scale is the constant electron Compton radius, not a mass-dependent Compton radius.

Lepton masses:

$m_e = 9.109x10^{-31}$
$m_{muon} = 1.883x10^{-28}$
$m_{tau} = 3.167 \; x \; 10^{-27}$

Compton radius calculated with these:

$r_e = 3.861x10^{-13}$
$r_{muon} = 1.868x10^{-15}$
$r_{tau} = 1.111x10^{-16}$

Electric field intensities calculated with their Compton radius;

$E_{muon} \quad = \; 5.66 \times 10^{22} \; (V/m)$
$E_{tau} \quad = \; 1.6 \times 10^{25} \quad (V/m)$

These values are several orders of magnitude higher than the maximum fields reported in the literature (Eur.Phys.J.C 76:428) $(10^{24} V/m)$ therefore , the "mass-dependent Compton radius" approximation is not physically valid.

When the Compton radius of the electron is used;

$E_{muon} \quad = \; 2.74 \times 10^{20} \, V/m$
$E_{tau} \quad = \; 4.6 \times 10^{21} \quad V/m$

These values are consistent with the range of field strengths discussed in heavy-ion collisions and in LHC measurements. Therefore, the physically relevant scale is not the Compton radius that varies with mass, but rather the fixed Compton radius of the electron.
These values indicate that the increase in lepton mass is directly proportional to the corresponding increase in electric field strength.

In this framework, the increase in lepton mass (and energy) can occur in two ways:

Relativistic energy increase:
Relativistic kinetic energy increases mass via $E = \; F \; x \, r \; x \, \gamma$

This corresponds to elongation of the helical structure, where the combined cylindrical and curvature radii change according to Lorentz factors. Since the local speed along the helix is always c,

the Frenet–Serret curvature radius is

$|v|^2 = v_z^2 + v_t^2 = c^2$

$(\rho)=\frac{|v|^3}{|VxA|}$ $|VxA|=\frac{V_t^2}{r}xc$ $(\rho)=\frac{c^3}{\frac{v_t^2}{r}xc}$ $(\rho)=rx\frac{c^2}{v_t^2}$ $v_t^2=c^2-v_z^2$ $(\rho)=rx\gamma^2$

and the cylindrical radius is

$R = rx\frac{v_t}{c}$ $R=\frac{r}{\gamma}$

Thus, one of the composite radii increases with $r_0 x\gamma^2$ while the other decreases with r_0/γ, giving:

$$r = \frac{r_0 x\gamma^2}{\gamma} \qquad r = r_0 x\gamma$$

Increase in internal force:
Here, the force $F = Exe$ arises from the internal electric field acting on the lepton's charge. If the lepton possesses an extremely strong internal electric field, the magnitude of F increases, and consequently its internal energy and effective mass also increase.This formulation suggests that all leptons are different energy-density states of the same underlying physical system. All massive leptons correspond to the same helical energy-path structure stabilized under different electric field strengths, while bosons may represent even higher-field composite states. Thus, mass emerges directly from the geometric curvature of energy paths and from the stabilization of light momentum via centripetal forces.