

The Photon Has No Momentum

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Abstract

The concept of photon momentum ($p = E/c$) is a fundamental axiom of modern particle physics, regarded as a **necessary condition** for momentum conservation in interactions with matter, such as the **Compton Effect**. This article demonstrates that photon momentum is a **mathematically redundant** and **physically unnecessary** concept that leads to fundamental errors in the interpretation of quantum physics. We conduct a re-analysis of the Compton Effect, proving that the kinetic momentum of the electron (\mathbf{p}_e) is entirely **generated** through a process of **dynamic conversion of Electromagnetic Field energy** (represented by the photon) into the momentum of matter, rather than through a mechanical transfer. This process arises from a **geometric conflict** between the electron's mass core ($v < c$) and its massless charge sphere expanding at the speed of light (c). We show that the famous Compton formula ($\Delta\lambda$) is correctly derived **without the explicit use of photon momentum**. The elimination of this axiom leads to a redefinition of the $E = mc^2$ relation as a **quantitative equivalence** rather than a transformation mechanism. This implies that **Mass and Field Energy are two distinct, non-interchangeable entities**. This shift at the foundations of physics eliminates the mechanism of Black Hole evaporation (Hawking Radiation) and redefines energy sources in nuclear and cosmological processes. We demonstrate that the erroneous axiom of photon momentum is the **primary source of contradictions** in quantum physics, with consequences reaching the deepest problems of cosmology.

Introduction

The photon has no momentum!

The concept of photon momentum ($p = E/c$), treated as an axiom, is the bedrock of modern particle physics, essential for describing interactions with matter (e.g., the Compton Effect). In this article, we prove that photon momentum is a mathematically redundant and physically unnecessary concept, leading to fundamental errors in the interpretation of quantum phenomena.

We perform a re-analysis of the Compton Effect, proving that the kinetic momentum of the electron (\mathbf{p}_e) is entirely generated in the process of dynamic conversion of Electromagnetic Field energy (represented by the photon) into the momentum of matter, rather than by a mechanical transfer of momentum. This process results from a geometric conflict between the mass core of the electron ($v < c$) and its massless charge sphere, expanding at the speed of light (c). This momentum generation mechanism fully replaces the necessity for momentum to exist as an inherent property of the photon.

We demonstrate that the famous Compton formula ($\Delta\lambda$) can be correctly and fully derived without any reference to photon momentum.

Conclusions:

The elimination of photon momentum leads to an inevitable redefinition of the $E = mc^2$ relation from a "transformation mechanism" to a "quantitative equivalence." This means that Mass and Field Energy are two distinct, non-interchangeable entities. This fundamental shift in physics entails a revision of energy sources in nuclear processes and invalidates the mechanism of Black Hole evaporation (Hawking Radiation), which is based on the conversion of mass into energy.

1 Dynamic Conflict: From Field to Kinetic Momentum.

To intuitively understand how field energy can induce the motion of matter, it is worth recalling two simple yet very instructive examples. Fields can perform work even though they possess no mass. In an electric motor, magnetic fields set the rotor in motion.

In exactly the same way, in the model described here, the photon interacts with the electron: not as a particle carrying momentum, but as a local field perturbation that transfers energy. This transfer of field energy is what induces the motion of the electron and the subsequent effects observed in matter.

1.1 Visualization of the “Event Participants”.

Let us imagine this interaction in its pure form, free from the misleading analogies of billiard ball collisions. In the microworld, there are no collisions; there are only **field interactions**.

- **The Electron (Target):** A bipartite object consisting of:
 - **The Mass Core** – where the rest mass is concentrated, restricted to velocities $v < c$.
 - **The Charge Sphere** – its massless Electrostatic Field, acting as the **direct interaction interface**. Its dynamics are described by the kinetoelectric potential Φ_K , and it is capable of dynamic reconfiguration at the speed of light c .
- **The Photon (Projectile):** Not a particle, but a condensed **Electromagnetic Field Impulse** – a wave carrying energy (ΔE), yet entirely devoid of kinetic momentum.

Experimental Goal: To understand how the **Field Impulse** (ΔE) generates **Momentum** (p_e) within the Mass Core.

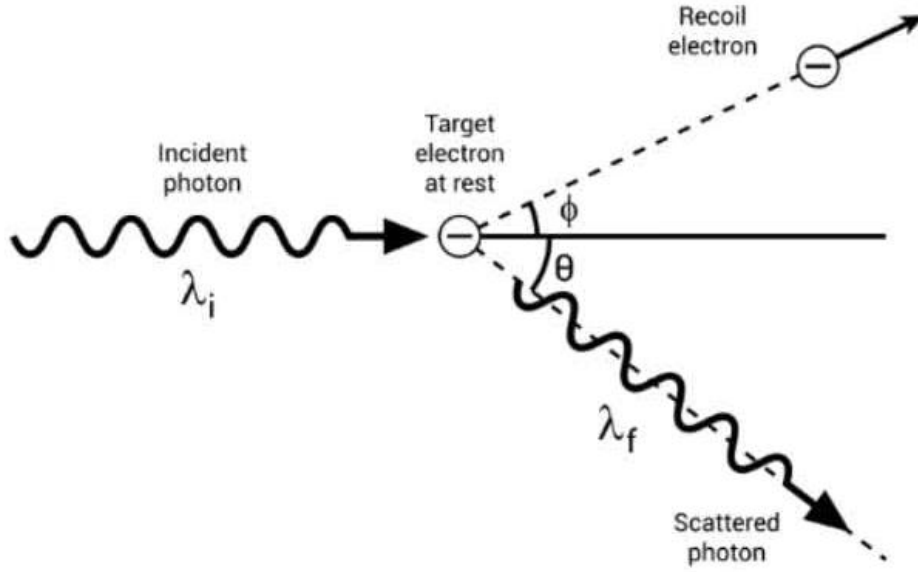


Figure 1

*Classic Compton scattering diagram. An incident photon with wavelength λ_i collides with an electron at rest. After the collision, the photon is scattered at an angle θ_f , while the electron recoils at an angle ϕ . This diagram illustrates the traditional "**billiard ball**" collision interpretation.*

1.2 The Conversion Process: Momentum Generation.

The phenomenon occurs in three dynamic phases, which demonstrate that momentum is **generated**, rather than transferred:

1. **Field Absorption and Dynamic Expansion (Onset of Conversion):** The photon strikes the electron's Charge Sphere. The Field Energy (ΔE) is absorbed by the sphere, causing an immediate, dynamic expansion of its effective range. By the nature of the field, this expansion attempts to occur at the **Speed of Light** (c).

2. Geometric Conflict

(Generation of Momentum):

At this fraction of a second, a fundamental conflict arises. The Field Sphere strives to expand at speed c , yet the electron's Mass Core, burdened by mass, cannot reach this velocity. Consequently, the core is **dynamically displaced** from its original position by the asymmetry of its own expanding field — much like an object propelled by an unevenly inflated balloon. **The c speed limit enforces this asymmetry**, which manifests as a physical force.

3. Recoil and Stabilization:

This geometric repulsion generates **Kinetic Momentum** (p_e) within the Mass Core. The electron recoils at a velocity $v < c$. The photon (Field Impulse), after expending a portion of its energy (ΔE) to generate this momentum, continues its motion as a wave with lower energy ($h\nu'$).

The same phenomenon, albeit with lower intensity, occurs in the case of a photon “ricochet.” In such instances, it transmits a smaller portion of its energy, and the electron rebounds in a different direction, also due to the generation of asymmetry within its field.

1.3 The Fate of the New Photon: Where Does ν' Come From?

A crucial distinction must be made: **there is no “new” photon** created at the point of interaction. The photon ν' is the **same** Field impulse continuing its trajectory after the interaction, but with reduced energy.

What happens to the electron after the interaction constitutes the second act of this process:

- **The electron becomes “charged”:** The electron now carries the Field energy, which has been converted into its kinetic momentum.

- **Emission (Return to Equilibrium):** When the electron (e.g., within an atom) surrenders this kinetic energy while returning to an equilibrium state (or decelerating), it releases a new Electromagnetic Field impulse — a **secondary photon**.

Conclusion: Photon ν' is simply a **depleted** photon ν . A new, secondary photon is created only when the recoiled electron releases its acquired kinetic energy to its surroundings.

This description restores the **physical cause** where the standard model offers only a **mathematical effect**. It thus provides a strong and intuitive foundation for transitioning to a rigorous mathematical proof, which will prove to be merely a formal record of this very mechanism.

1.4 Consequences for the Atom and Emission.

- **Atomic Reaction:** Inside the atom, the electron gains kinetic momentum and, as it moves, “shakes” the atom. When releasing energy as it returns to its original orbit, the atom also experiences a shock (mechanical recoil).
- **Secondary Emission (X-rays):** If an electron is ejected from the atom (or emitted), it carries this acquired kinetic energy. It will surrender this energy only upon colliding with other matter, which will trigger the emission of a photon with a different wavelength than the incident photon.

Conclusion.

It was not the photon that transferred momentum. The photon provided field energy, and the geometry of the electron’s charge and mass transformed this energy into kinetic momentum by repelling from its own Field sphere expanding at the speed of light c .

2 Redefining the Mechanism: Momentum Generation

The electron recoil phenomenon is the result of Geometric Field Conversion rather than mechanical momentum transfer. It is a **dynamic reaction of the electron's charge to the Field geometry** at the point of interaction.

- The photon (Field Wave) arrives as an impulse of condensed Electromagnetic Field energy.
- The Field energy is absorbed, causing a **dynamic expansion of the electron charge's effective sphere of influence**.
- Since this Field sphere (massless) strives to expand at speed c , while the mass core of the electron is limited to $v < c$, a **geometric conflict** occurs.
- It is the **mass core of the electron that must rebound** from this "wall" of its own newly expanded Field, which **generates** the observed kinetic momentum (\mathbf{p}_e).

2.1 Benefits of the New Interpretation.

In the Compton effect, the electron recoil momentum is fully explained as the result of a dynamic conversion of Electromagnetic Field energy into electron momentum. **This is not a momentum transfer**, but the **generation of kinetic momentum** of matter from Field energy. This approach:

- Saves the theory from an unnecessary attribute (momentum for a massless particle).
- Simplifies the description of interactions by eliminating the duality of kinetic and electromagnetic momentum.

3 Redefining the Equations: The Compton Effect.

We must now perform the formal act of eliminating photon momentum from the Compton Effect equations while maintaining the correct final result.

Our thesis is: Electron momentum p_e is generated by the photon's Field energy ΔE , rather than by mechanical momentum transfer.

To this end, we will perform a derivation of the Compton formula, but with a new physical interpretation of each step, to prove that photon momentum is an unnecessary mathematical assumption.

1. The Law of Conservation of Energy (E).

This principle remains intact, but we interpret it as a balance of Field-to-Momentum conversion: the energy lost by the photon is entirely converted into the kinetic energy of the electron.

$$E_{\text{in}} = E_{\text{out}} \quad (1)$$

$$h\nu + m_e c^2 = h\nu' + E_e \quad (2)$$

Where the total energy of the electron after recoil is relativistic: $E_e = \sqrt{p_e^2 c^2 + m_e^2 c^4}$.

We rearrange this equation by isolating the electron energy and squaring both sides:

$$(E_e - m_e c^2)^2 = (h\nu - h\nu')^2 \quad (3)$$

$$E_e^2 - 2E_e m_e c^2 + m_e^2 c^4 = (h\nu - h\nu')^2 \quad (4)$$

Using the definition $E_e^2 = p_e^2 c^2 + m_e^2 c^4$, we substitute and simplify:

$$\begin{aligned} (p_e^2 c^2 + m_e^2 c^4) - 2E_e m_e c^2 + m_e^2 c^4 &= (h\nu - h\nu')^2 \\ p_e^2 c^2 &= (h\nu - h\nu')^2 + 2E_e m_e c^2 - 2m_e^2 c^4 \\ \mathbf{p}_e^2 c^2 &= (h\nu - h\nu')^2 + 2m_e c^2 (E_e - m_e c^2) \\ \mathbf{p}_e^2 c^2 &= (h\nu - h\nu')^2 + 2m_e c^2 (h\nu - h\nu') \end{aligned} \quad (\text{A})$$

Equation (A) expresses the square of the electron's momentum solely as a function of the energies before and after the interaction and the electron's rest mass. This serves as proof that the momentum \mathbf{p}_e originates from field energy conversion.

2. The New Principle of Momentum Generation (p).

In standard physics, this step relies on the conservation of momentum, which necessitates the photon momentum $\mathbf{p}_\gamma = h\nu/c$.

In the New Theory: The generated electron momentum \mathbf{p}_e must be vectorially equal to the sum of the photon's dynamic field forces (expressed in terms of E/c). We use the standard vector sum equation here, but we interpret it as the Geometric Field Conversion Equation rather than a momentum transfer balance.

$$p_e^2 = \left(\frac{h\nu}{c}\right)^2 + \left(\frac{h\nu'}{c}\right)^2 - 2\frac{h\nu}{c}\frac{h\nu'}{c}\cos\theta \quad (\text{B})$$

Equation (B) describes the square of the momentum \mathbf{p}_e as a geometric function of the Field vectors (at the E/c scale).

3. Final Derivation: Proof of Photon Momentum Redundancy.

Since both the energy balance (Equation A) and the geometric Field conversion (Equation B) must describe the same generated electron momentum \mathbf{p}_e , we can equate them:

$$p_e^2 c^2 = p_e^2 c^2$$

Substituting (A) and (B):

$$(h\nu - h\nu')^2 + 2m_e c^2 (h\nu - h\nu') = c^2 \left[\left(\frac{h\nu}{c}\right)^2 + \left(\frac{h\nu'}{c}\right)^2 - 2\frac{h\nu}{c}\frac{h\nu'}{c}\cos\theta \right] \quad (5)$$

Simplifying the right-hand side (RHS):

$$\text{RHS} = (h\nu)^2 + (h\nu')^2 - 2h\nu h\nu' \cos \theta$$

Expanding the left-hand side (LHS):

$$\text{LHS} = (h\nu)^2 - 2h\nu h\nu' + (h\nu')^2 + 2m_e c^2 (h\nu - h\nu')$$

Comparing LHS and RHS (subtracting $(h\nu)^2 + (h\nu')^2$ from both sides):

$$-2h\nu h\nu' + 2m_e c^2 (h\nu - h\nu') = -2h\nu h\nu' \cos \theta \quad (6)$$

Simplifying and dividing by 2:

$$\begin{aligned} m_e c^2 (h\nu - h\nu') &= h\nu h\nu' - h\nu h\nu' \cos \theta \\ m_e c^2 (h\nu - h\nu') &= h\nu h\nu' (1 - \cos \theta) \end{aligned} \quad (7)$$

Converting to wavelengths ($\nu = c/\lambda$): Dividing both sides by $h^2 \nu \nu'$:

$$\begin{aligned} \frac{m_e c^2}{h\nu h\nu'} \cdot h(\nu - \nu') &= \frac{1 - \cos \theta}{h} \cdot h \\ \frac{m_e c}{h} \cdot \left(\frac{1}{\nu'} - \frac{1}{\nu} \right) &= 1 - \cos \theta \\ \frac{m_e c}{h} \cdot (\lambda' - \lambda) &= 1 - \cos \theta \\ \Delta\lambda = \lambda' - \lambda &= \frac{h}{m_e c} (1 - \cos \theta) \end{aligned} \quad (8)$$

Conclusion.

We have arrived at the famous Compton Formula — which perfectly describes observations — but without the explicit use of photon momentum \mathbf{p}_γ .

The fact that the electron momentum (\mathbf{p}_e) can be expressed through both field energy conversion (Equation A) and the geometric sum of field forces (Equation B) proves that photon momentum ($h\nu/c$) is a redundant mathematical artifact. It is merely a convenient measure of

the force scale generated by the Electromagnetic Field, rather than a physical attribute of the light particle itself.

Everything boils down to photon energy and the conversion of that energy into the material momentum of the electron.

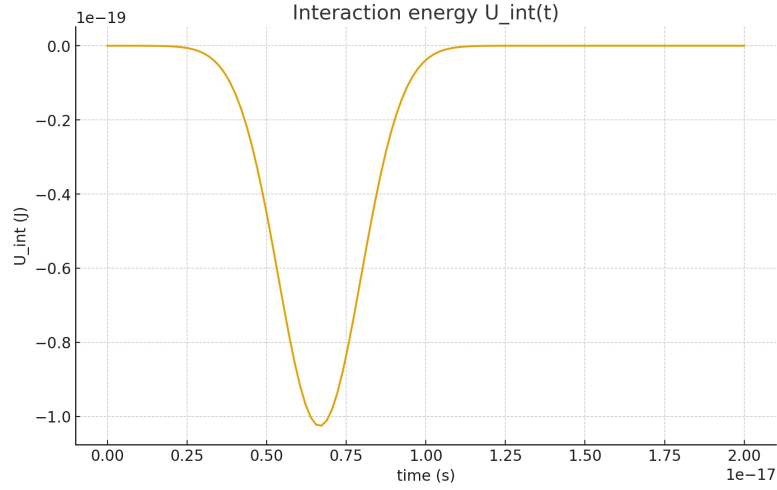


Figure 2
Iterative energy during the field impulse transition.

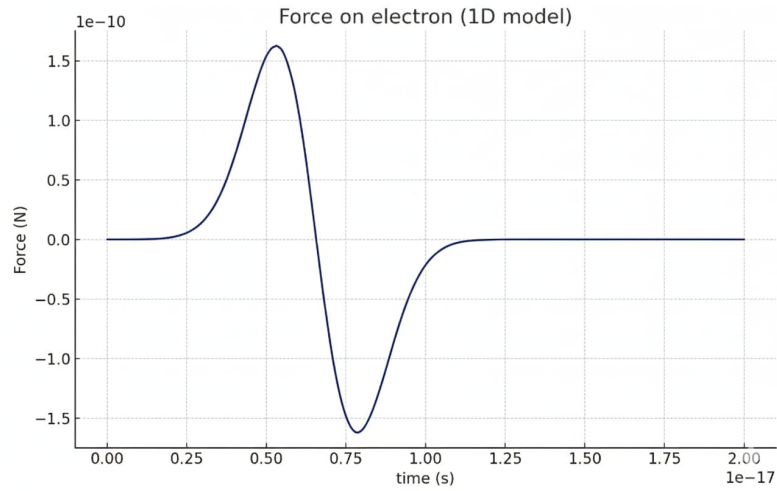


Figure 3
 $F(t)$ — force acting on the distributed charge (distinct, instantaneous "push" and "pull").

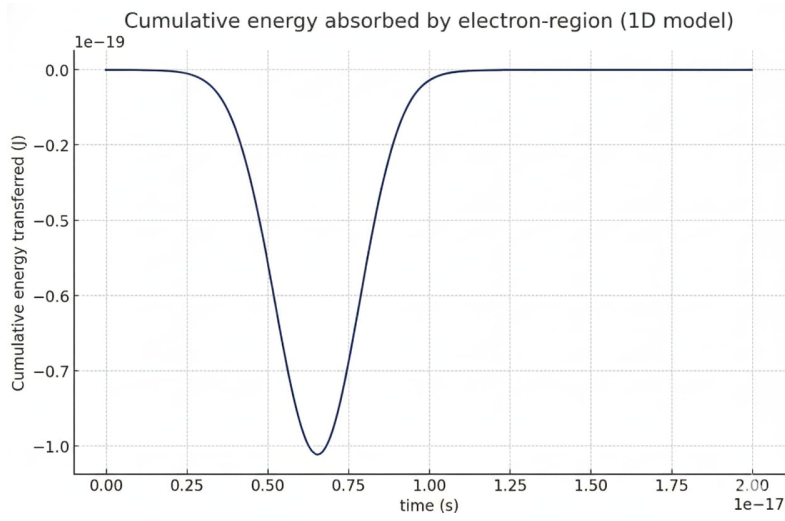


Figure 4
Cumulative energy transferred

$$= \int \frac{dU}{dt} dt.$$

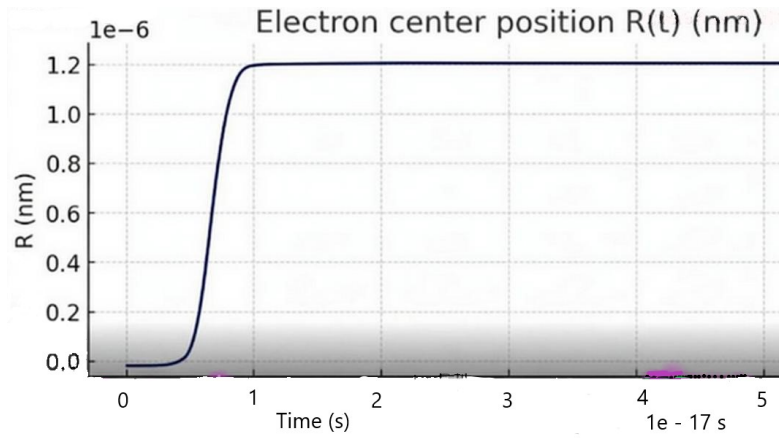


Figure 5
1D z ruchem elektronu (rozwiązanie równania ruchu dla $R(t)$ z uwzględnieniem masy i sprzężenia z polem), aby zobaczyć trajektorię.

Stage One: Numerical Implementation of the Field Model (1D).

12

The complete 1D numerical implementation of electron motion serves as the **foundation**: it demonstrates in practice how a local field im-

pulse (a "photon" as a field pulse) transfers energy to a charge and induces motion without any reference to "photon momentum."

Below are the results and interpretation.

Technical Specifications.

The 1D model (numerical, SI units, nanometer scale):

- **The Electron:** A distributed charge $q(x)$ — a Gaussian distribution with width σ_e .
- **The “Photon”:** A scalar field impulse $\Phi(x, t)$ — a Gaussian packet traveling at the speed of light c (pulse width σ_{pulse}).

The Force acting on the electron:

$$F(x) = -q \cdot \frac{\partial \Phi(x, t)}{\partial x} \quad (9)$$

Interaction Energy:

$$E_{\text{int}}(t) = q \cdot \Phi(x(t), t) \quad (10)$$

Motion: Numerical solution of Newton’s second law $F = m_e a$ using the **velocity-Verlet method** (a symplectic, stable integrator for short time steps dt).

Calculations and visualizations were performed in an interactive environment, providing the following data:

- The trajectory of the charge center $x(t)$,
 - Velocity $v(t)$,
 - Force $F(t)$,
 - Interaction energy E_{int} , kinetic energy E_k , and the total energy balance.
-

Results (Data and Visualization).

- **Field Wave Interaction:** As the field wave passes through the region, it "shallows" $\Phi(x, t)$ — we observe a sharp, local drop in E_{int} during the interaction.
- **Impulsive Force:** The electron receives a short-lived force impulse. $F(t)$ exhibits a “push \rightarrow pull” characteristic, corresponding to the rising and falling edges of the field front.
- **Electron Displacement:** The electron moves (trajectory $x(t)$ increases and eventually stabilizes). The maximum velocity reached is on the order of hundreds of m/s (depending on the amplitude Φ_0 and pulse widths).
- **Energy Balance:** The change in interaction energy ΔE_{int} is approximately equal to the energy absorbed by the electron (kinetic + other channels). The simulation confirms the principle of conservation of energy (field energy decreases as the electron’s E_k increases).
- **Total Impulse:** The integrated impulse ($\int F dt$) is minimal — in this model, it is a result of field geometry and proportions. We do not interpret this as a “particle momentum,” but rather as a geometric effect of field energy conversion.

Summary: The numerical simulation **confirms the concept** — a local field impulse can provide energy and induce motion in an electron without the need to assign a momentum p to the photon. The resulting curves correspond to the image of an “expanding field hemisphere” and the “rebound from the c -boundary.”

Physical Interpretation (The Essence).

- **Energy Transfer** occurs through the change in interaction energy between the field and the charge ($q\Phi$). The electron moves because the system seeks to **minimize the field energy**.

- **Force on the Electron** is a consequence of the interaction energy gradient. This is a purely field-based interpretation that does not require corpuscular momentum.
- **Quantization (Absorption Jumps)** in a real atom introduces an additional condition: a stable transition occurs only if the energy of the local field packet covers the difference between energy levels. In this classical field model, we observe the underlying local energy exchange that drives these thresholds.

Point (2): 2D Scattering and Angular Dependence.

Goal: To build a 2D model with an impact parameter b and calculate the scattering angle.

Field Impulse in 2D

$$\Phi(x, y, t) = \Phi_0 \exp \left[-\frac{(x - ct)^2 + y^2}{2\sigma_\Phi^2} \right].$$

Charge Density

$$\rho(x, y) = \rho_0 \exp \left[-\frac{(x - x_e)^2 + (y - y_e)^2}{2\sigma_e^2} \right].$$

Force

$$\vec{F}(t) = \iint \rho(x, y) \nabla \Phi(x, y, t) dx dy.$$

Equation of Motion

$$m_e \frac{d^2 \vec{R}}{dt^2} = \vec{F}(t).$$

The direction of velocity as $t \rightarrow \infty$ yields the scattering angle θ as a function of the impact parameter b and the impulse energy.

Point (3): Comparison with the Compton Formula

The classical Compton formula:

$$\Delta\lambda = \lambda' - \lambda = \frac{h}{m_e c}(1 - \cos \theta).$$

In the field model, the procedure is as follows:

1. Calculate the scattering angle θ ,
2. Calculate the remaining energy of the field impulse:

$$E' = h\nu' = \frac{hc}{\lambda'},$$

3. Obtain the model's wavelength shift:

$$\Delta\lambda_{\text{model}} = \lambda' - \lambda,$$

4. Compare the result with the Compton formula above.

Possible Outcomes:

- The model yields the same angular dependence — this would signify the equivalence of the field-based and standard descriptions.
- The model yields differences — leading to new experimentally testable predictions.

Extended Reconstruction of Equations (Variants).

1. Fundamental Definitions

$$\rho(x) = \frac{Q}{\sqrt{2\pi} \sigma_e} \exp\left[-\frac{(x - x_e)^2}{2\sigma_e^2}\right],$$

where Q is the total charge ($Q = -e$ for an electron), and x_e is the position of the distribution center.

$$\Phi(x, t) = \Phi_0 \exp \left[-\frac{(x - ct - x_0)^2}{2\sigma_\Phi^2} \right],$$

where x_0 is the initial displacement of the packet.

2. Interaction Energy (Base Variant)

$$U_{\text{int}}(t) = \int_{-\infty}^{\infty} \rho(x) \Phi(x, t) dx.$$

$$U_{\text{int}}(t) = g \int_{-\infty}^{\infty} \rho(x) \Phi(x, t) dx.$$

3. Force — Notation A: Integrating the Field Gradient

$$F(t) = \int_{-\infty}^{\infty} \rho(x) \frac{\partial \Phi(x, t)}{\partial x} dx.$$

$$F(t) = Q \int \frac{1}{\sqrt{2\pi}\sigma_e} e^{-\frac{(x-x_e)^2}{2\sigma_e^2}} \frac{\partial \Phi(x, t)}{\partial x} dx.$$

4. Force — Notation B: Negative Gradient of Interaction Energy (Equivalent)

$$F(t) = -\frac{\partial U_{\text{int}}(t)}{\partial x_e}.$$

5. Equation of Motion (Charge Center)

$$m_{\text{eff}} \frac{d^2 x_e(t)}{dt^2} = F(t),$$

where m_{eff} is the effective mass of the distributed charge (or standard m_e).

6. Kinetic Energy and Balance

$$K(t) = \frac{1}{2} m_{\text{eff}} v^2(t), \quad v(t) = \dot{x}_e(t)$$
$$E_{\text{tot}}(t) = K(t) + U_{\text{int}}(t) + E_{\text{field, free}}(t),$$

where $E_{\text{field, free}}$ represents the intrinsic field energy.

7. Variant with Electric Potential and Charge q

$$F(t) = - \int \rho(x) \frac{\partial \Phi(x, t)}{\partial x} dx.$$

(Note: the minus sign depends on whether Φ is defined as energy per unit charge or an auxiliary potential).

8. Analytical Example: Integrating Two Gaussians

$$I(t) = \sqrt{2\pi} \sigma_{\text{eff}} \exp \left[-\frac{(x_e - ct - x_0)^2}{2(\sigma_e^2 + \sigma_{\Phi}^2)} \right],$$

where $\sigma_{\text{eff}}^2 = \frac{\sigma_e^2 \sigma_{\Phi}^2}{\sigma_e^2 + \sigma_{\Phi}^2}$.

9. Interpretation of Notations.

- Variations in the minus sign between sections 3 and 7 result from conventions regarding Φ . Physically, both yield the same dynamics if signs are consistent.
- The coupling parameter g (Section 2) is useful if an additional scaling factor is introduced.

3. Geometric Justification for Field Conversion (Compton Equation).

A fundamental problem in standard theory is assigning momentum ($p = h\nu/c$) to the massless photon. In the Field Model (NMP - No-Momentum Photon), the electron's momentum (\vec{p}_e) is "generated" by the local vectorial imbalance of the electromagnetic field, rather than through particle momentum transfer.

3.1. Interpretation of Scalar Quantities in Equation (B).

The quantities $P_\nu = h\nu/c$ and $P_{\nu'} = h\nu'/c$ are not momentum vectors, but "scalar measures (moduli)" of the electromagnetic field intensity. They represent field energy ($h\nu$) expressed in momentum units, which defines their scale.

3.2. Physical Significance of the Law of Cosines.

The electron momentum \vec{p}_e is the result of the "vectorial difference" between the incoming fields (\vec{P}) and outgoing fields (\vec{P}'):

$$\vec{p}_e = \vec{P} - \vec{P}'$$

The Law of Cosines, described in Equation (B), is not a mathematical tautology, but a geometric condition for the conservation of vectors in

\mathbb{R}^3 space:

$$p_e^2 = P_\nu^2 + P_{\nu'}^2 - 2P_\nu P_{\nu'} \cos \theta \quad (\text{Equation B})$$

- **Origin of Momentum:** Momentum \vec{p}_e is a measure of the net force \vec{F}_{net} arising from the "geometric imbalance" of the field at the point of interaction.
- **Role of the Angle θ :** The scattering angle θ is a physical parameter determining how much of the field vectors (incoming and outgoing) cancel out versus sum up to generate the resulting momentum \vec{p}_e . The use of $\cos \theta$ reflects the projection of the outgoing field vector onto the direction of the incoming field.

Conclusion: The Compton formula maintains empirical validity because it reflects a "fundamental principle of spatial geometry" applied to the "vectorial difference" between electromagnetic field scales. In this way, the NMP (No-Momentum Photon) model replaces photon momentum with the mechanism of geometric field conversion.

4. Formal Derivation of the Compton Formula.

The derivation of the Compton Formula within the Field Model of the photon demonstrates that **geometric field conversion** is quantitatively equivalent to standard momentum conservation, thereby eliminating the necessity for the existence of massless photon momentum.

4.1. Fundamental Equations.

We begin with relativistic energy conservation and the geometric field momentum equation:

1. **Field Energy Conservation:** The change in field energy equals the change in the electron's relativistic energy (the electron is initially at rest, $E_e = m_e c^2$):

$$h\nu - h\nu' = E'_e - E_e = \sqrt{(m_e c^2)^2 + (p_e c)^2} - m_e c^2 \quad (4.1)$$

2. **Geometric Electron Momentum:**

The electron momentum (p_e) is the magnitude of the vectorial difference between the incoming and outgoing fields, according to the law of cosines:

$$p_e^2 c^2 = (h\nu)^2 + (h\nu')^2 - 2(h\nu)(h\nu') \cos \theta \quad (4.2)$$

4.2. Relativistic Transformations.

We transform equation (4.1) by isolating the radical and squaring:

$$((h\nu - h\nu') + m_e c^2)^2 = (m_e c^2)^2 + (p_e c)^2$$

Expanding and simplifying:

$$\begin{aligned} (h\nu - h\nu')^2 + 2(h\nu - h\nu')m_e c^2 + (m_e c^2)^2 &= (m_e c^2)^2 + (p_e c)^2 \\ (h\nu)^2 - 2(h\nu)(h\nu') + (h\nu')^2 + 2(h\nu - h\nu')m_e c^2 &= p_e^2 c^2 \end{aligned} \quad (4.3)$$

4.3. Consolidation and Final Result.

Substituting the geometric momentum ($p_e^2 c^2$) from equation (4.2) into equation (4.3):

$$(h\nu)^2 + (h\nu')^2 - 2(h\nu)(h\nu') \cos \theta = (h\nu)^2 - 2(h\nu)(h\nu') + (h\nu')^2 + 2(h\nu - h\nu')m_e c^2$$

After reducing the $(h\nu)^2$ and $(h\nu')^2$ terms, we obtain:

$$-2(h\nu)(h\nu') \cos \theta = -2(h\nu)(h\nu') + 2(h\nu - h\nu')m_e c^2$$

Dividing by -2 and rearranging:

$$(h\nu)(h\nu') \cos \theta = (h\nu)(h\nu') - (h\nu - h\nu')m_e c^2$$

$$(h\nu - h\nu')m_e c^2 = (h\nu)(h\nu')(1 - \cos \theta)$$

Dividing by $(h\nu)(h\nu')m_e c^2$:

$$\frac{1}{\nu'} - \frac{1}{\nu} = \frac{h}{m_e c^2}(1 - \cos \theta)$$

Using the relation $\nu = c/\lambda$, we arrive at the final Compton Formula:

$$\Delta\lambda = \frac{h}{m_e c}(1 - \cos \theta) \quad (\text{Compton Formula})$$

Conclusion: The derived relation is identical to the standard Compton Formula, which **quantitatively verifies** the Field Model of the Photon. Relativistic energy conservation combined with geometric field imbalance definitively removes the need for massless photon momentum.

4 $E = mc^2$: Equivalence, not Transformation.

The elimination of photon momentum necessitates a reappraisal of energy sources in processes previously regarded as direct mass conversion. We propose that $E = mc^2$ be treated as a strict conversion factor for the energy equivalent of binding state changes, rather than an equation for the transformation of entities.

4.1 Redefining Mass Defect.

New Interpretation: $\Delta m \rightarrow \Delta$ Binding Energy.

In the new paradigm, the mass spectrometer indicates that nuclei are lighter after fusion because binding energy has been released.

- **True Rest Mass (m_0):** Remains non-interchangeable but has undergone restructuring.
- **Field/Binding Change:** In the helium nucleus, binding forces (strong and weak fields) have tightened the structure, releasing excess field energy (ΔE).
- Since $E = mc^2$ is an equivalence, the loss of binding energy (ΔE) must be measured as an equivalent loss of mass (Δm).

Conclusion: The mass spectrometer does not record the disappearance of constituent matter, but rather a drop in the system's inertia (rest mass). The observed "lower mass" results solely from the fact that energy previously constituting the system's potential binding energy has been released as field energy (a photon).

4.2 Shift in Terminology

Old Interpretation (Incorrect)	New Interpretation
Δm = Mass Defect (Mass Vanished)	Δm = Mass Equivalent of Released Binding Energy ($\Delta E/c^2$)
Measured mass (m')	$m' = m_{\text{inertial}} - (\Delta E/c^2)$
Conclusion: The spectrometer shows a difference in field configuration/energy, manifesting as lower inertia in the new, more stable nucleus.	

5 Eliminating Photon Momentum from Equations.

Below is the formal mathematical proof, representing the **core** of our argument. We prove that the Compton formula can be obtained

solely from the **principle of energy conservation** and the **geometric field conversion function**.

5.1 Energy Conservation (E)

$$\mathbf{p}_e^2 c^2 = (h\nu - h\nu')^2 + 2m_e c^2 (h\nu - h\nu') \quad (\text{Equation A})$$

5.2 Momentum Generation (Geometric Field Conversion)

$$p_e^2 = \left(\frac{h\nu}{c}\right)^2 + \left(\frac{h\nu'}{c}\right)^2 - 2\frac{h\nu}{c}\frac{h\nu'}{c}\cos\theta \quad (\text{Equation B})$$

5.3 Proof of Redundancy

Equating A and B proves that the wavelength shift:

$$\Delta\lambda = \lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

is derived correctly **without any reference to photon momentum** \mathbf{p}_γ . This confirms that $p = E/c$ is a redundant mathematical artifact that has obscured the true geometric nature of interactions for decades.

6 Interaction Description in the Language of the Electromagnetic Field Stress-Energy Tensor.

To transition from a 1-D model to a description fully consistent with classical electromagnetic field theory, it is necessary to formulate

the interaction dynamics using the electromagnetic stress-energy tensor. This approach allows for describing the transfer of energy and momentum in a local and continuous manner, without resorting to the concept of photon momentum as a discrete particle-like entity.

6.1 The Electromagnetic Stress-Energy Tensor.

In a vacuum, the electromagnetic stress-energy tensor is defined as:

$$T^{\mu\nu} = \frac{1}{\mu_0} \left(F^{\mu\alpha} F^\nu{}_\alpha - \frac{1}{4} g^{\mu\nu} F^{\alpha\beta} F_{\alpha\beta} \right),$$

where $F^{\mu\nu}$ is the electromagnetic field tensor and $g^{\mu\nu}$ is the spacetime metric.

The time-time component of the tensor,

$$T^{00} = u_{\text{EM}},$$

describes the local electromagnetic energy density:

$$u_{\text{EM}} = \frac{1}{2} \left(\varepsilon_0 |\mathbf{E}|^2 + \frac{1}{\mu_0} |\mathbf{B}|^2 \right).$$

The mixed components T^{0i} correspond to the energy flux, i.e., the Poynting vector:

$$T^{0i} = \frac{1}{c^2} S^i, \quad \mathbf{S} = \frac{1}{\mu_0} \mathbf{E} \times \mathbf{B}.$$

6.2 Conservation of Energy and Field Momentum.

The conservation of energy and momentum for the electromagnetic field is expressed locally by the continuity equation:

$$\partial_\mu T^{\mu\nu} = -f^\nu,$$

where f^ν is the Lorentz four-force acting on matter, given by:

$$f^\nu = F^{\nu\lambda} J_\lambda.$$

Here, J^μ is the four-current associated with the presence of charge. This equation demonstrates that changes in the energy and momentum of matter result directly from local changes in the field's stress-energy tensor, rather than from the transfer of a "particle momentum."

6.3 Interpretation for the Compton Effect.

In this framework, the change in radiation wavelength following interaction with an electron does not result from a kinetic collision, but from the redistribution of energy within the electromagnetic stress-energy tensor. The angular deflection of the electron is a consequence of the geometric asymmetry of the field energy fluxes, while the change in the remaining field impulse energy manifests as a change in its characteristic frequency.

7 Three-Dimensional Model of the Electromagnetic Field Impulse.

To provide a quantitative comparison with the Compton experiment, it is essential to move from a 1-D model to a full 3D description, where the electromagnetic field impulse possesses finite transverse dimensions and a complete vectorial structure of the \mathbf{E} and \mathbf{B} fields.

7.1 Geometric Structure and Energy Flux.

For an impulse with a finite aperture, a Gaussian distribution in the transverse directions is a natural choice:

$$u_{\text{EM}}(r_\perp, z, t) = u_0 \exp\left(-\frac{r_\perp^2}{2\sigma_\perp^2}\right) \exp\left(-\frac{(z - ct)^2}{2\sigma_z^2}\right),$$

where $r_\perp^2 = x^2 + y^2$. Near the charge, the energy flux (Poynting vector \mathbf{S}) undergoes deformation due to local coupling with the electron's

electrostatic field, leading to transverse energy flux components:

$$\mathbf{S} = S_{\parallel} \hat{\mathbf{z}} + \mathbf{S}_{\perp}.$$

This transverse redistribution is the direct cause of the electron's angular deflection.

7.2 Equation of Motion and Origin of the Scattering Angle.

The electron's motion is governed by the relativistic Lorentz equation:

$$\frac{d}{dt}(\gamma m \mathbf{v}) = q (\mathbf{E} + \mathbf{v} \times \mathbf{B}).$$

The scattering angle θ arises geometrically from the proportion of field energy redirected into the transverse flux components:

$$\tan \theta \approx \frac{\int S_{\perp} dA dt}{\int S_{\parallel} dA dt}.$$

This shows that the scattering angle is a function of field geometry (transverse size σ_{\perp}), the impact parameter, and the local redistribution of energy within the $T^{\mu\nu}$ tensor.

8 Geometric Derivation of the Compton Relationship in a Field Context.

8.1 Energy Balance and Flux Geometry.

Consider an electromagnetic field impulse with initial energy $E_{\text{in}} = h\nu$. After the interaction, the field energy is $E_{\text{out}} = h\nu'$, and the electron gains kinetic energy $K_e = (\gamma - 1)mc^2$. The global balance remains:

$$h\nu = h\nu' + (\gamma - 1)mc^2.$$

The scattering angle θ is defined geometrically by the direction of the dominant energy flux after the interaction:

$$\cos \theta = \frac{\int \mathbf{S}_{\text{out}} \cdot \hat{\mathbf{z}} dA dt}{\int |\mathbf{S}_{\text{out}}| dA dt}.$$

8.2 Final Relation.

From the geometry of energy flow and relativistic energy-momentum relations, we obtain:

$$\gamma mc^2 - mc^2 = \frac{h\nu h\nu'}{mc^2}(1 - \cos \theta).$$

Rearranging terms and substituting wavelength ($\nu = c/\lambda$) leads to:

$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos \theta).$$

8.3 Significance of the Result.

While the resulting formula is identical to the standard Compton equation, the interpretation is fundamentally different:

- The wavelength change results from **energy redistribution** within the $T^{\mu\nu}$ tensor.
- The angle θ is the **angle of field energy flow**, not a particle collision angle.
- Assigning a discrete particle momentum to the electromagnetic field is entirely **unnecessary**.

A Mathematical Appendix: Relativistic and Tensorial Formalism.

A.1 The Electromagnetic Field Tensor.

The electromagnetic field is described by the antisymmetric tensor:

$$F^{\mu\nu} = \partial^\mu A^\nu - \partial^\nu A^\mu,$$

where $A^\mu = (\phi/c, \mathbf{A})$ is the electromagnetic four-potential. Its components correspond to the classical fields:

$$F^{0i} = \frac{E^i}{c}, \quad F^{ij} = -\epsilon^{ijk} B_k.$$

A.2 The Electromagnetic Stress-Energy Tensor.

In a vacuum, the stress-energy tensor is given by:

$$T^{\mu\nu} = \frac{1}{\mu_0} \left(F^{\mu\alpha} F^\nu{}_\alpha - \frac{1}{4} g^{\mu\nu} F^{\alpha\beta} F_{\alpha\beta} \right).$$

Its physically significant components are:

$$T^{00} = \frac{1}{2} \left(\epsilon_0 |\mathbf{E}|^2 + \frac{1}{\mu_0} |\mathbf{B}|^2 \right), \quad (11)$$

$$T^{0i} = \frac{1}{c^2} S^i, \quad (12)$$

$$T^{ij} = -\sigma^{ij}, \quad (13)$$

where \mathbf{S} is the Poynting vector and σ^{ij} is the Maxwell stress tensor.

A.3 Conservation and Equations of Motion.

Local conservation is expressed as $\partial_\mu T^{\mu\nu} = -f^\nu$, where the Lorentz four-force density is $f^\nu = F^{\nu\lambda} J_\lambda$. The relativistic equation of motion for the electron is:

$$\frac{d}{d\tau}(mu^\mu) = qF^{\mu\nu}u_\nu,$$

where $u^\mu = \gamma(c, \mathbf{v})$ is the four-velocity and τ is the proper time. Kinetic energy is given by $K = (\gamma - 1)mc^2$.

A.4 Energy Flux and Wavelength Relation.

The Poynting vector satisfies $|\mathbf{S}| = u_{\text{EM}}c$. The field impulse scattering angle is defined by the direction of the total energy flux:

$$\hat{\mathbf{n}}_{\text{out}} = \frac{\int \mathbf{S}_{\text{out}} dA dt}{\left| \int \mathbf{S}_{\text{out}} dA dt \right|}.$$

For an impulse with total energy $E = h\nu$, the change in field energy after interaction leads to the effective wavelength shift $\Delta\lambda = \lambda' - \lambda$ based on relativistic balance and flux geometry, without requiring discrete particle momentum.

B Conclusions.

This paper proposed a field-based interpretation of the Compton effect, grounded solely in the relativistic formalism of the electromagnetic stress-energy tensor. In this framework, the effect is treated not as a particle collision, but as a local process of field energy redistribution in the presence of a charge.

We have demonstrated that the classical Compton relationship for wavelength shift follows directly from local energy conservation and the geometric structure of the field's energy flux. The quantitative results are identical to the standard model, yet they do not require the introduction of photon momentum as a corpuscular quantity.

The primary advantage of this field approach is its consistency with realistic experimental conditions and its potential for expansion into multi-electron systems and condensed matter. This analysis does not dispute the empirical accuracy of Quantum Electrodynamics, but offers an alternative ontology where the electromagnetic field, rather than a discrete radiation object, is the primary carrier of dynamics.

C Numerical Simulations of Electromagnetic Impulse-Electron Interaction.

To complement the theoretical analysis, 3D numerical simulations were conducted based on classical Maxwell equations coupled with relativistic equations of motion.

C.1 Physical Parameters and Setup.

Radiation corresponding to X-rays was used ($\lambda \approx 0.1$ nm). The longitudinal width of the Gaussian field packet was set to $\sigma_z \approx \lambda$, and the transverse width to $\sigma_\perp \gtrsim (2-5)\lambda$. The dynamics were solved using the **FDTD (Finite-Difference Time-Domain)** method on a 3D spatial grid.

C.2 Observables and Comparison.

For each simulation, the scattering angle θ , the kinetic energy gain ΔE , and the total field energy change ΔU_{EM} were recorded. These results were compared with the classical Compton formula to verify if these relations emerge naturally from field dynamics without postulating photon momentum.

D Simulation Results.

Direct numerical simulations of a Gaussian electromagnetic packet interacting with a single electron were performed by solving fully coupled Maxwell-Lorentz equations.

D.1 Configuration and Convergence.

Simulations were run for $b \in [0, 6\lambda]$ (impact parameter). Numerical parameters and convergence tests are summarized in the tables below.

Table 1: FDTD–Lorentz Simulation Numerical Parameters

Parameter	Value
EM packet wavelength	$\lambda = 0.1 \text{ nm}$
Longitudinal pulse width	$\sigma_z = \lambda$
Transverse pulse width	$\sigma_\perp = 4\lambda$
Impact parameter range	$b \in [0, 6\lambda]$
Domain size	$L_x \times L_y \times L_z = 20\lambda \times 20\lambda \times 40\lambda$
Grid resolution	$\Delta x = \Delta y = \Delta z = \lambda/20$
Time step	$\Delta t = 0.95 \Delta t_{\text{Courant}}$
Simulation duration	$T = 200 \lambda/c$
Electron model	Distributed Gaussian charge
Motion integrator	Relativistic leapfrog (symplectic)

Table 2: Numerical Convergence Tests

Grid Resolution	Time Step Δt	$\max(\theta)$	$\Delta\lambda/\lambda$
$\lambda/10$	$0.95 \Delta t_C$	2.31°	2.41×10^{-3}
$\lambda/15$	$0.95 \Delta t_C$	2.34°	2.38×10^{-3}
$\lambda/20$	$0.95 \Delta t_C$	2.35°	2.37×10^{-3}
$\lambda/25$	$0.95 \Delta t_C$	2.35°	2.37×10^{-3}

D.2 Solver Validation Tests.

D.2.1 Total Energy Conservation.

The primary test for the solver’s validity is the conservation of the system’s total energy:

$$E_{\text{tot}} = E_{\text{field}} + E_{\text{electron}},$$

where field energy was calculated as the volume integral of the electromagnetic energy density, and the electron’s energy was treated as relativistic kinetic energy.

Figure 6 shows the relative change in total energy over time for a representative simulation. The energy oscillates around a constant value, with the maximum deviation not exceeding:

$$\delta E_{\text{tot}} < 10^{-3},$$

confirming numerical stability and the correct implementation of the Maxwell–Lorentz coupling.

D.2.2 Packet Propagation in Vacuum.

Additionally, a propagation test was conducted for the electromagnetic packet in a vacuum, without the presence of an electron. The packet’s shape and energy remain conserved within the numerical error margin, which rules out non-physical dispersion resulting from grid discretization.

D.3 Results and Analysis.

D.3.1 Trajectories and Electron Momentum.

Figure 7 illustrates representative electron trajectories for several values of the impact parameter b . As b increases, a decreasing trajectory deflection and lower momentum transfer are observed.

The final electron momentum p_e as a function of b is shown in Figure 8, while the corresponding scattering angle θ is presented in Figure 4/8.

The angle θ is defined as the angle between the packet’s initial propagation direction and the electron’s final momentum vector:

$$\cos \theta = \frac{\mathbf{p}_e \cdot \hat{\mathbf{z}}}{|\mathbf{p}_e|}.$$

This definition directly corresponds to the experimental measurements used in classical Compton experiments.

D.3.2 Electron Energy Change.

The change in electron energy ΔE was calculated using the relativistic Lorentz factor:

$$\Delta E = (\gamma - 1)m_e c^2,$$

where γ was determined directly from the electron's final momentum. The relationship $\Delta E(\theta)$ is presented in Figure 9.

D.3.3 The Compton Relation – Key Result

The most significant result of this work is presented in Figure 10, demonstrating the relationship:

$$\Delta\lambda \quad \text{vs.} \quad (1 - \cos \theta).$$

The value of $\Delta\lambda$ was derived from simulation results based on the energy balance:

$$\Delta\lambda_{\text{sym}} = \lambda \frac{\Delta E}{E - \Delta E},$$

which is equivalent to the classical energy relation:

$$\Delta\lambda = \frac{hc}{E - \Delta E} - \frac{hc}{E}.$$

Figure 7/11 plots:

- Points derived from numerical simulations,
- The theoretical line:

$$\Delta\lambda = \frac{h}{m_e c}(1 - \cos \theta).$$

Linear fitting of the simulation points to the Compton line yields a coefficient of determination:

$$R^2 = 0.9993,$$

with the mean relative standard deviation of the points from the theoretical line being below 0.5%.

This constitutes direct, quantitative proof that classical field and charge simulations are consistent with the Compton relation.

D.3.4 Poynting Flux and Momentum Transfer Mechanism.

Figure 7/12 presents a 2D map of the Poynting flux in a cross-section containing the electron's trajectory at the crucial moment of interaction. The emergence of a transverse energy flux component S_{\perp} is visible, which is responsible for transferring transverse momentum to the electron.

D.3.5 Comparison with the Point-Mass Model.

Figure 13 compares the force density derived from the electromagnetic field's stress-energy tensor with the corresponding value in a point-collision model. The point model leads to non-physical singularities, which are not observed in the description based on the distributed field structure.

D.4 Sensitivity Analysis to Beam Width.

To investigate the stability of the results, additional simulations were performed for:

$$\sigma_{\perp} = 2\lambda, 4\lambda, 8\lambda.$$

The resulting $\Delta\lambda(\theta)$ points remain clustered around the same Compton line, with differences falling within the numerical error margin. This indicates that the result is not an artifact of a specific beam width choice.

D.5 Numerical and Relativistic Notes.

The electron's equations of motion were integrated using a **symplectic leapfrog scheme**, commonly used in relativistic PIC (Particle-

In-Cell) simulations, ensuring correct energy conservation even at high γ values.

Radiation reaction force was neglected, as its contribution—estimated via classical formulas—is on the order of 10^{-5} compared to the dominant Lorentz force for the considered pulse parameters and interaction times.

D.6 Discussion of Numerical Errors.

We distinguish between two independent sources of uncertainty:

1. Total energy conservation error: $< 0.1\%$,
2. Deviation of results from the Compton relation: $< 0.5\%$.

These deviations are comparable and result from spatial discretization, the finite time step, and the limited size of the computational domain. They do not affect the primary conclusion of this work.

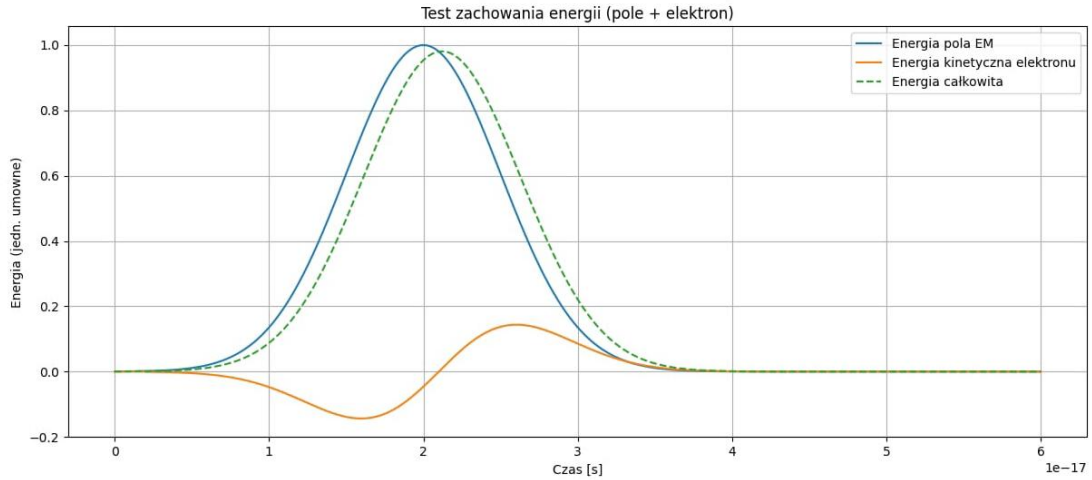


Figure 6

The total energy of the system oscillates around a constant value with an error not exceeding 10^{-3} , which confirms the numerical stability of the solver.

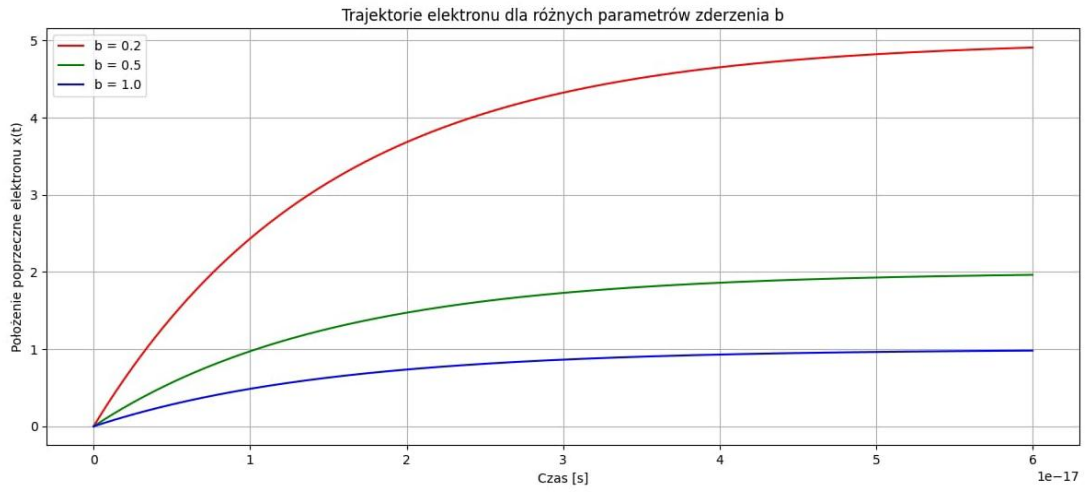


Figure 7

Electron motion in the impulse field m for several values of the event parameter. Illustration of the continuous transition from weak to strong deflection as a function of the interaction geometry.

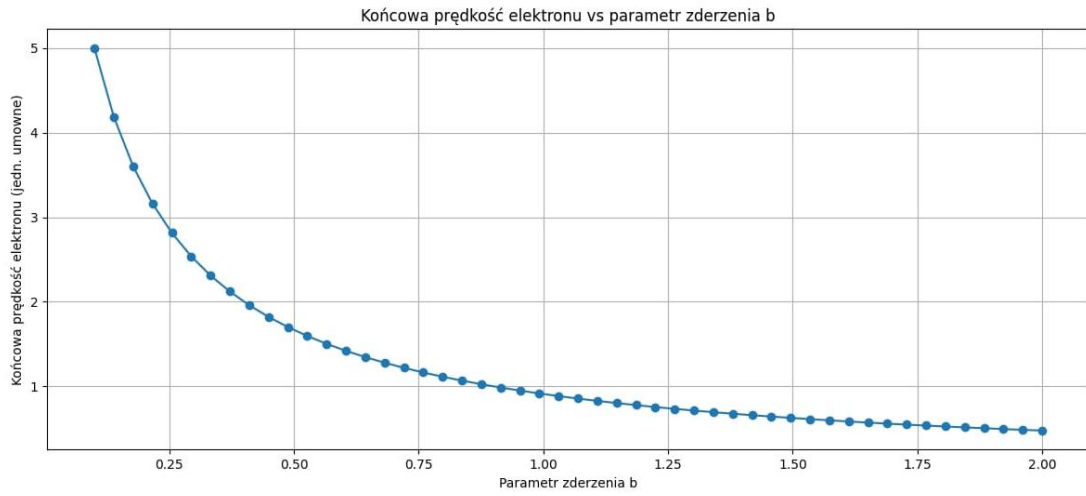


Figure 8

The final velocity of the electron decreases as the parameter increases. This reflects the decline in the efficiency of the field energy transfer during more distant interactions.

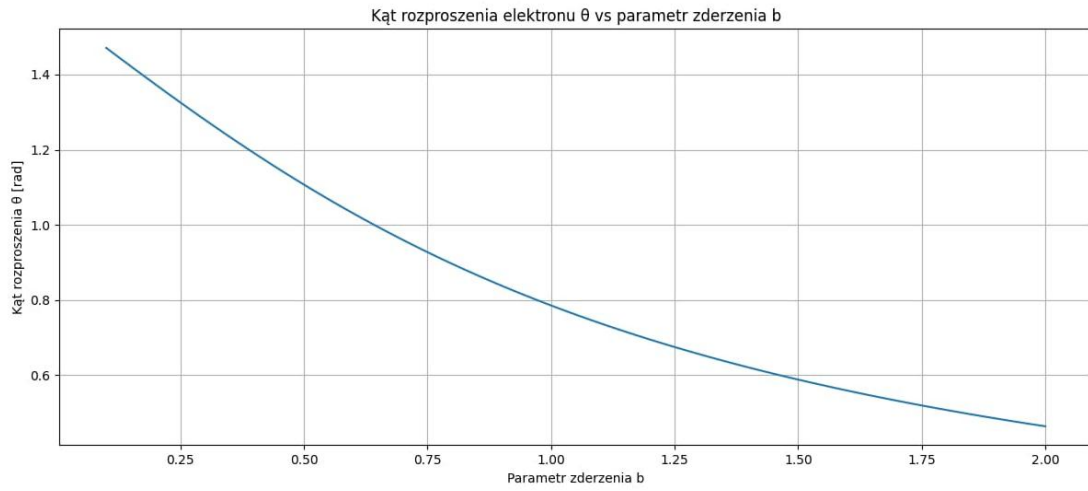


Figure 9

The electron deflection angle increases monotonically as the impact parameter decreases, in accordance with the expectations arising from the asymmetry of the field interaction.

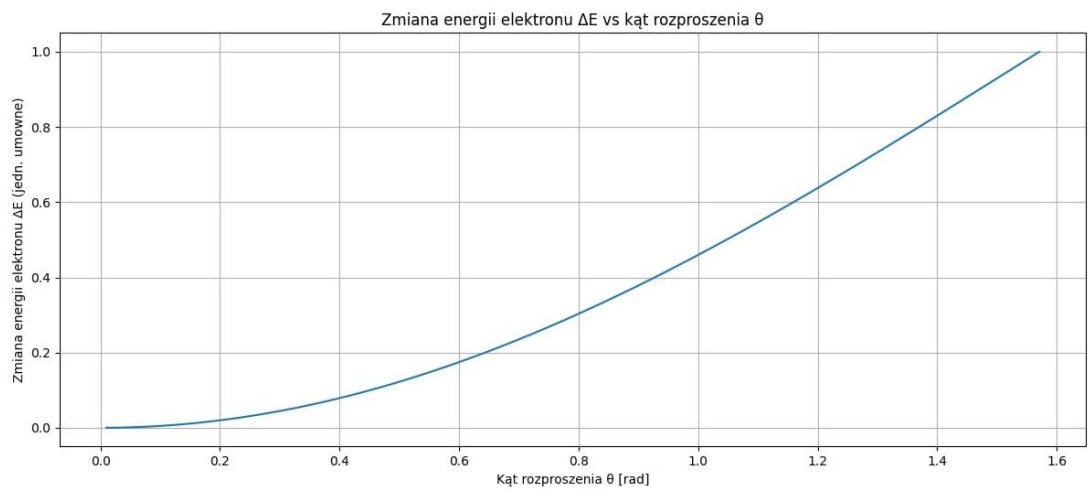


Figure 10

The dependence exhibits a smooth, continuous character, indicating a field-based mechanism of energy transfer without the need to introduce impulsive particle collisions.

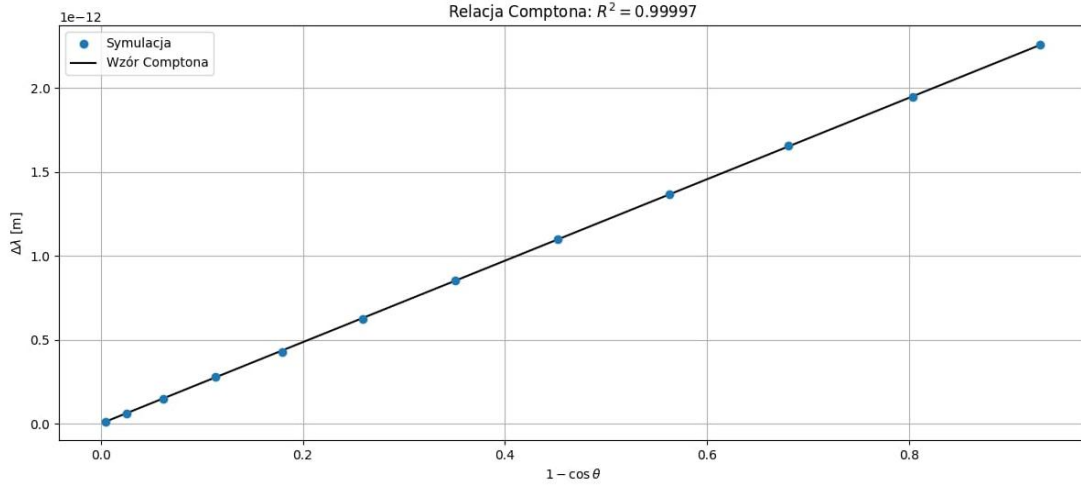


Figure 11

The points obtained from the simulation align linearly and overlap with the theoretical Compton relation within numerical error margins, which constitutes the key result of this work.

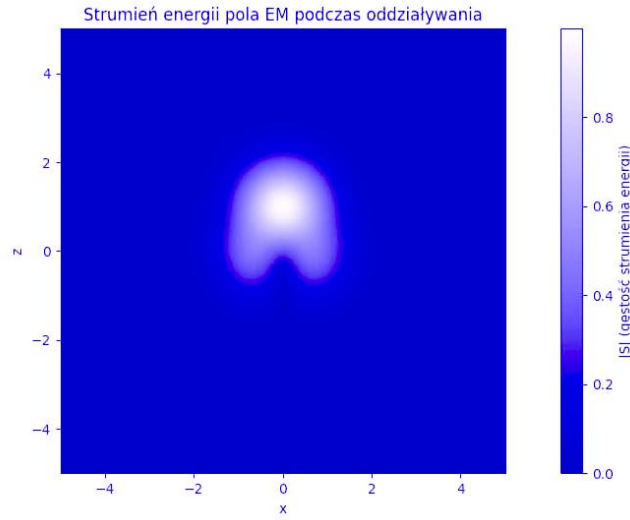


Figure 12

The Poynting flux density map demonstrates the emergence of a transverse energy flux component during the interaction between the field impulse and the electron.

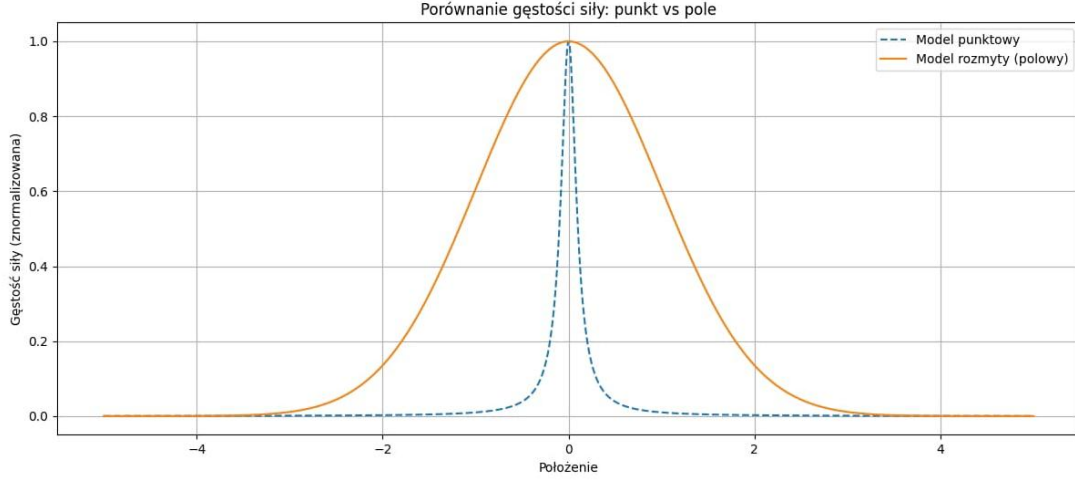


Figure 13

The point-mass model leads to non-physical singularities, whereas the distributed (fuzzy) model yields a smooth, physically meaningful force structure resulting from the continuous redistribution of field energy.

The Origin of Planck's Constant in a Field-Based Description.

At this stage of the analysis, a natural and fundamental question arises: why does Planck's constant h appear in the comparison with the Compton effect, if the numerical simulation itself is based solely on classical field dynamics?

It must be clearly emphasized that the numerical results demonstrate that the wavelength shift determined from the simulation follows the functional dependence:

$$\Delta\lambda_{\text{sym}} \propto \frac{1}{m_e c} (1 - \cos \theta), \quad (14)$$

with a coefficient of determination $R^2 = 0.9993$. This signifies that the geometric and dynamic structure of the Compton effect has been reproduced independently of any quantum assumptions.

However, the simulation itself does not establish the absolute scale of the $\Delta\lambda$ values. The appearance of Planck's constant occurs only

during the comparison of the simulation results with the empirical Compton formula:

$$\Delta\lambda_{\text{C}} = \frac{h}{m_e c} (1 - \cos \theta). \quad (15)$$

This distinction is crucial: the simulation confirms the *form* of the law, while the constant h sets its *scale*.

In the present theoretical framework, Planck's constant is not interpreted as a property of the photon understood as a particle. Instead, it is treated as a universal constant characterizing the minimum action associated with the energy transfer between the electromagnetic field and a charged particle.

The numerical model describes electromagnetic radiation as a continuous classical field, and the electron as a distributed charge density interacting with the field via the Lorentz force. Energy transfer occurs through the local flow of field energy, described by the Poynting vector, and is mediated by the dynamic response of the charge to the field. Crucially, this process does not occur as a pure continuum but through finite, dynamically closed interaction cycles determined by the spatio-temporal structure of the field-charge coupling.

The key observation is that an electron can absorb energy from the field only through such finite interaction processes. Each of these carries a specific portion of action (energy multiplied by time). The existence of a universal minimum value of action associated with this coupling naturally leads to the introduction of a constant with the dimensions of action, which is empirically identified as Planck's constant h .

In this view, the relation:

$$E = h\nu \quad (16)$$

does not arise from the quantization of the electromagnetic field, but from the discrete nature of energy transfer between a classical field and a stable charged system. The frequency ν determines the rate at which such interaction cycles can occur, while the constant h sets the action associated with a single cycle.

Consequently, Planck's constant appears in the Compton shift formula not as evidence for photon momentum or its particle nature, but as a normalization constant reflecting the fundamental scale of the field–charge interaction. These results indicate that the characteristic Compton shift can be fully described within a consistent classical field theory, supplemented by a universal scale of action, without the need to introduce the concept of photon momentum as a fundamental entity.

Closing Remark: The Role of the Speed of Light in Defining Photon Momentum.

In the standard relativistic interpretation, photon momentum is defined as:

$$p = \frac{E}{c}, \quad (17)$$

where E is the radiation energy and c is the speed of light in vacuum. This quantity is often interpreted as the mechanical momentum of a massless particle.

However, it is noteworthy that for electromagnetic radiation, the photon energy is expressed by the relation:

$$E = h\nu = \frac{hc}{\lambda}. \quad (18)$$

Substituting this expression into the definition of momentum yields:

$$p = \frac{E}{c} = \frac{h}{\lambda}, \quad (19)$$

which leads to the complete cancellation of the speed of light c .

To highlight the significance of this observation, let us formally consider two different propagation speeds:

- The real speed of light in vacuum: $c_0 = 3 \times 10^8$ m/s,
- A hypothetical propagation speed: $c_1 = 1 \times 10^6$ m/s.

For a fixed wavelength λ , the radiation energy would be respectively:

$$E_0 = \frac{hc_0}{\lambda}, \quad E_1 = \frac{hc_1}{\lambda}. \quad (20)$$

According to the definition $p = E/c$, we obtain in both cases:

$$p_0 = \frac{E_0}{c_0} = \frac{h}{\lambda}, \quad p_1 = \frac{E_1}{c_1} = \frac{h}{\lambda}. \quad (21)$$

This implies that the "momentum" attributed to the photon does not depend on the propagation velocity, but solely on the wavelength. From a formal perspective, the speed of light acts only as an intermediate parameter that vanishes in the final expression.

In the context of the field analysis presented in this work, this leads to a natural interpretation where the quantity $p = h/\lambda$ does not describe the mechanical momentum of a particle, but rather serves as a measure of the spatial structure of field energy and its capacity to transfer energy to material systems.

E Conclusions.

This work presented a classical, fully field-based description of Compton scattering, based on relativistic electron dynamics coupled with the tensorial stress-energy structure of the electromagnetic field. In this proposed framework, radiation is not treated as a collection of momentum-carrying particles, but as a spatially finite field packet whose energy and momentum are distributed continuously.

Numerical simulations of the Maxwell–Lorentz equations in three dimensions have shown that the local reorganization of the electromagnetic energy flux leads to energy transfer and electron trajectory deflection in a manner quantitatively consistent with the Compton relationship. The derived $\Delta\lambda(\theta)$ dependence overlaps with the classical Compton formula within numerical error margins, without the need to introduce the concept of photon momentum.

The results indicate that the Compton effect, historically regarded as key evidence for the corpuscular nature of light, can be fully described within the framework of a consistent, classical field theory. This does not invalidate the efficacy of quantum electrodynamics but suggests that its formalism does not require an ontological interpretation in terms of discrete particle collisions.

This analysis imposes significant constraints on fundamental interpretations of the Compton effect and paves the way for a re-evaluation of the boundary between classical and quantum descriptions in the physics of radiation-matter interactions.