

# Electromagnetic Basis of Gravity and Inertia in Classical Systems

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## ABSTRACT

This paper proposes that all classical mechanical and gravitational effects observed in ordinary matter originate from electromagnetic interactions. It argues that inertia, contact forces, and gravitational curvature arise entirely from the electromagnetic field energy generated by charged particles, even in neutral systems. By establishing a one-to-one correspondence between gravitational and electromagnetic potentials, the theory shows that relativistic phenomena—such as time dilation and length contraction—naturally result from electromagnetic field energy. The framework, termed electrorelativity, unifies electrodynamics and general relativity in classical systems without invoking additional forces, particles, or fields. Gravity emerges as a statistical average of countless small-scale electromagnetic interactions, explaining its apparent weakness compared to electromagnetism. This reinterpretation eliminates the need for a separate gravitational field and asserts that the electromagnetic field itself serves as the physical background of spacetime and governs all observable classical motion. The framework is limited to classical systems, with high-energy and quantum-scale effects left for future work.

## Keywords:

Electrorelativity, Electromagnetism, Field energy, Gravity, Inertia, Length contraction, Mass–energy equivalence, Ordinary matter, Relativistic effects, Time dilation

## MOTIVATION—A CLASSICAL FOUNDATION FOR UNIFICATION

This framework is written using classical mechanics, electrodynamics, and general relativity in a form that physicists a century ago would recognize. The reason is simple: a quantum theory of gravity cannot be built without first establishing a complete classical foundation. If gravity and electromagnetism are to be unified at the quantum level, they must first be unified classically. While the framework draws occasional motivation from quantum results where useful, its formulation remains within classical physics, offering a reinterpretation of gravitational behavior based on electromagnetic field energy.

## FIELD SYMMETRY IN CLASSICAL SPACE: ELECTROMAGNETISM AS A GRAVITATIONAL ANALOG

There is an exact mapping between the spatial structure of classical electromagnetic fields and gravitational fields. Both radiate outward from localized sources in a spherically symmetric manner—each field obeys an inverse-square law, and their associated potentials fall off inversely with distance. Since both the electromagnetic and gravitational field structures share the same spatial rules, it becomes plausible that they share a common basis.

This structural parallel holds regardless of whether the two interactions stem from a common origin. Even if one does not accept the hypothesis that electromagnetism produces gravity, the correspondence remains a powerful and usable model for gravitational dynamics. The electromagnetic field is familiar, observable, and easier to analyze, while gravity is typically presented in terms of curvature and geodesics. By translating gravitational behavior into electromagnetic terms, the physics becomes more tangible—especially when relativistic effects are considered.

## WHAT IS ORDINARY MATTER?

Ordinary matter is the type of matter that makes up everything we directly observe in the universe: atoms, molecules, stars, planets, and living organisms. It is composed of protons, neutrons, and electrons. These particles form atoms, which combine into molecules and build macroscopic structures. Ordinary matter is the only type of matter described

by classical laws, defining the scope of both classical mechanics [1] and the framework presented in this paper.

## POSTULATE 1: INERTIA, MOMENTUM, AND STRESS ARE ELECTROMAGNETIC IN CLASSICAL MECHANICS

In classical mechanics, mass appears in virtually every equation governing motion and interaction: Newton’s second law, kinetic energy, momentum, collisions, friction, tension, pressure, and more. Yet in all of these contexts—outside of gravity—the physical origin of the forces involved is electromagnetic. All observable motion is classical, because human instruments only detect electromagnetic behavior at macroscopic scales. Every experiment involving pressure, acceleration, impact, or inertia is mediated by electromagnetic fields [2].

Even internal resistance to acceleration—what we call “inertial mass”—reflects how the object’s internal charge distribution responds to changing external electromagnetic fields [2]. Contact forces arise from the repulsion of electron clouds due to Coulomb’s law [2]. Normal force, tension, and friction are all manifestations of electromagnetic interactions between the charged particles that make up materials. When two objects collide, their constituent electrons repel one another, and the resulting deceleration is described using mass as a convenient stand-in for electromagnetic resistance to acceleration [2].

While general relativity normally treats the stress-energy tensor  $T^{\mu\nu}$  as a sum of contributions from matter and other fields, this paper proposes that, for ordinary matter, the electromagnetic field alone accounts for the full stress-energy content—thereby producing not only mechanical forces but also gravitational and inertial effects traditionally attributed to mass [3]. This identifies the electromagnetic field as the sole contributor to mechanical behavior in classical systems [2].

## POSTULATE 2: ORDINARY MATTER EMITS RADIATION INDUCING RELATIVISTIC EFFECTS

In systems composed of ordinary matter, opposite charges do not cancel in a strict or complete sense. Instead, their effects average out at macroscopic scales. Even when a particle is surrounded by other charges in a configuration that produces zero net force, it does not remain perfectly still. Rather, it

continues to fluctuate in position and momentum—absorbing and emitting electromagnetic energy—due to the unresolved, uneven contributions of nearby fields. These fluctuations are a direct result of continuous photon exchanges and are not suppressed by net charge neutrality [4]. In fact, the more charges there are, and the closer they are packed, the more energetically the particle fluctuates, even if it exhibits no net motion on large scales [4]. The surrounding electromagnetic field remains active, continually driving the particle’s response.

This postulate is supported by the fact that no physical system is truly static at the atomic level. All particles are in constant electromagnetic exchange with their environment [4]. Even electrically neutral systems, such as hydrogen molecules and helium atoms, exhibit spectral lines, emit radiation, and undergo collision forces—demonstrating that electromagnetic interactions persist despite a net charge of zero [5].

Charge oscillations in a source mass generate energy in the surrounding field, causing slight fluctuations and shifts in nearby particle positions. While these fluctuations do not produce large-scale motion, they do induce persistent relativistic effects in nearby test masses—a central claim developed and formalized in this paper.

### ELECTROMAGNETIC FOUNDATIONS OF MASS–ENERGY EQUIVALENCE

Mass is defined as an object’s resistance to acceleration under an applied force: an object with greater mass requires greater force to produce the same change in motion [3]. Since all forces acting on ordinary matter are electromagnetic at the macroscopic level, this resistance arises from the object’s electromagnetic response to external fields [2].

Moreover, because all classical equations involving mass—such as Newton’s laws, kinetic energy, and momentum—are derived from measurements made with physical instruments governed by electromagnetic principles, the very form of these equations reflects electromagnetic interactions [2]. The resistance of an object to acceleration, its mechanical stiffness, and its energy content are all determined by the behavior of its electromagnetic field under external forces. In this sense, mass is operationally determined by probing an object’s electromagnetic field and measuring the resulting response.

In classical mechanics, mass is operationally defined by its electromagnetic interaction properties [6]. The conceptual link between energy and inertia set the stage for Einstein’s revolutionary 1905 work on special relativity, in which he formalized the mass–energy equivalence. In his original 1905 paper, Einstein explicitly derived the mass–energy equivalence equation [6]:

$$E = m c^2, \quad (1)$$

in terms of light energy (electromagnetic radiation).

In German, he stated, "Wenn ein Körper die Energie  $L$  in Form von Lichtstrahlung abgibt, so verkleinert sich seine Masse um  $L \div (9 \times 10^{16})$ , wobei die Energie in Erg und die Masse in Gramm gemessen wird." Translated to English, Einstein stated, "If a body emits the energy  $L$  in the form of light radiation, its mass diminishes by  $L \div (9 \times 10^{16})$ , where energy is measured in ergs and mass in grams" [6].

Light radiation here means electromagnetic energy. Einstein’s insight marked a turning point—suggesting that mass is not a fundamental quantity, but a manifestation of energy, particularly electromagnetic energy.

### THE SPEED OF LIGHT AND THE ELECTROMAGNETIC STRUCTURE OF SPACE

In classical physics, the speed of light is not treated as an arbitrary constant, but as a direct consequence of the properties

of the electromagnetic field. James Clerk Maxwell’s unification of electricity and magnetism in the 19th century led to the realization that light is an electromagnetic wave [2]. From Maxwell’s equations in vacuum, the speed of propagation of electromagnetic waves  $c$  is given by [2]:

$$c = \frac{1}{\sqrt{\epsilon_0 \mu_0}}, \quad (2)$$

where  $\epsilon_0$  is the vacuum permittivity, and  $\mu_0$  is the vacuum permeability.

This relation shows that the value of  $c$  is determined by the electromagnetic properties of the vacuum, rather than being an arbitrary or externally imposed constant [2]. Therefore, spatial variations in electromagnetic field energy can modify the relativistic structure experienced by a test particle in a manner that produces effects such as time dilation, redshift, and geodesic curvature—without requiring any change in the locally measured speed of light. This perspective supports the broader thesis that electromagnetic fields are not only responsible for force interactions in ordinary matter but also for the relativistic structure of spacetime itself.

### RELATIVISTIC EFFECTS OF ELECTROMAGNETIC FIELD ENERGY

In Newtonian mechanics, gravity is described as a force arising from mass–energy, but this description leaves the origin of that force unexplained. General relativity reinterprets gravity not as a force but as the curvature of spacetime caused by energy and momentum. This opens the possibility that, for ordinary matter, the energy responsible for spacetime curvature is entirely electromagnetic in origin [3].

The electromagnetic field around any object made of ordinary matter stores energy in space. When a second object—a test mass—enters this region, it interacts with this field energy, altering its own internal energy and producing relativistic effects.

Because these electromagnetic interactions occur between the charges within the test mass and the external electromagnetic field of the source object, they induce fluctuations in the test mass’s internal dynamics [4]. These fluctuations include atomic vibrations, electron transitions, quantum fluctuations, and chemical bond rearrangements [4], but generally involve any internal kinetic motion [2].

Since these fluctuations involve massive constituents undergoing continuous changes in velocity—that is, accelerations—they produce relativistic effects [3]. The resulting time dilation and length contraction are given by [3]:

$$t = \frac{t_0}{\gamma}, \quad (3)$$

and

$$L = L_0 \gamma, \quad (4)$$

where:

- $t$  is the dilated time measured by an inertial observer at infinity,
- $t_0$  is the proper time in the rest frame of the test object,
- $L$  is the contracted length measured by an inertial observer at infinity, and
- $L_0$  is the proper length in the rest frame of the test object.

In the weak-field limit, the Lorentz factor  $\gamma$ , which quantifies time dilation and length contraction due to relative motion or energy content, is approximated by [3]:

$$\gamma \approx 1 + \frac{U}{m c^2}, \quad (5)$$

where  $m$  is the test mass, and  $U$  is the potential energy gained by the test mass from the source electromagnetic field.

## MODELING THE ELECTROMAGNETIC BACKGROUND POTENTIAL

Since electromagnetic forces operate between the constituent charges of matter, we propose modeling their collective effect as a net background potential  $U$  representing the total magnitude of all pairwise electromagnetic interactions between the charges of the source and test objects, regardless of whether they are attractive or repulsive. This approach reflects Postulate 2, that even when net forces cancel, electromagnetic interactions persist and contribute to the field energy density. Relativistic effects depend on this total field energy, not the direction of the net force [3]. Since no standard formulation exists for this cumulative potential, we propose the following expression as a first-order approximation:

$$U = - \sum_s \sum_t |V_{st}|, \quad (6)$$

where:

- $s \in S$  indexes individual charges in the source object,
- $t \in T$  indexes individual charges in the test object,
- $V_{st}$  is the electromagnetic interaction potential between charge  $s$  and charge  $t$ .

This approximation is presented for illustration purposes, providing the reader with a clear sense of the physical behavior under consideration. The overall negative sign ensures that this potential behaves analogously to gravitational potential: it is negative-valued and decreases (becomes more negative) as distance decreases, consistent with an attractive interaction like gravity. In a full relativistic quantum treatment, this cumulative potential would be replaced by a field operator describing the electromagnetic field of the source, with the test object modeled as a quantum system interacting with this field.

## POTENTIALS MAPPING

Given that Postulate 1 states the electromagnetic field alone accounts for the full contents of the stress-energy tensor  $T^{\mu\nu}$ , and that general relativity relates it directly to the Einstein tensor  $G^{\mu\nu}$  through Einstein's field equation [3]:

$$G^{\mu\nu} = \frac{8\pi G}{c^4} T^{\mu\nu}, \quad (7)$$

which maps energy-momentum content to spacetime curvature, the Newtonian gravitational constant  $G$  becomes the required scaling factor between electromagnetic field energy and the curvature effects we observe as gravity.

To formalize the correspondence, gravitational potential energy is assigned an equivalent electrostatic form. This is justified because gravitational and electrostatic potentials share the same spatial structure: both decrease proportionally with distance from a localized source, and both arise from fields that diminish with the square of the distance. Given this parallel, it is natural to define a one-to-one mapping between them. This is not a derivation but a definitional identification, aligning their forms and scaling for consistency. We therefore equate the electrostatic and gravitational potentials by assigning [3]:

$$U = - \frac{G M m}{r}, \quad (8)$$

where  $M$  is the source mass, and  $m$  is the test mass.

Expressing the electromagnetic potential in terms of mass ensures that the resulting acceleration reproduces the expected gravitational behavior for a test object. Together, these expressions demonstrate that electromagnetic interactions alter local spacetime measurements. These relativistic effects are the observed warping of spacetime: the test object's experience of time and space is directly modified by the electromagnetic field.

## GRAVITATIONAL MOTION FROM ELECTROMAGNETIC TIME DILATION

Gravity arises from gradients in spacetime structure: time runs slower and spatial intervals contract near matter, guiding all motion along curved paths [3]. As a test object approaches a source, its constituent particles gain electromagnetic energy and begin to fluctuate more strongly. These internal motions produce relativistic effects, causing time to slow down for each particle. Because both gravitational and electromagnetic field strengths decrease with distance following an inverse-square law, the time dilation and length contraction gradients produced by electromagnetic fields mirror the structure of gravitational potential in general relativity [2]. The closer the object gets, the more electromagnetic energy it gains, and the more its proper time slows and its spatial length contracts in response. This gradient in curvature bends the path of nearby objects in agreement with gravitational theory [3].

## ELECTRORELATIVITY

This paper coins the term electrorelativity to describe the relativistic behavior that arises from electromagnetic energy alone. The associated electrorelativistic effects include time dilation, length contraction, and curved motion, all resulting from electromagnetic interactions in classical systems. These effects do not require any additional forces or new physics beyond electromagnetism and general relativity.

The only potentially speculative element in this model is the choice of  $G$  as the proportionality constant, used to match the scale of the standard gravitational potential. All preceding results follow directly from the postulates stated in this paper. It remains possible, however, that this effect is negligible outside of classical systems—where additional processes may contribute to gravity. But no alternative mechanism has yet been identified that accounts for gravitational behavior in terms of known physical interactions.

## SCALING: THE APPARENT WEAKNESS OF GRAVITY

Two predictions that follow logically from the reasoning developed throughout this paper:

### PREDICTION 1.

Many readers will instinctively struggle with the idea that electromagnetic radiation alone can produce relativistic effects at gravitational scales. The author initially shared this skepticism, having been influenced—like most physicists—by the deeply ingrained association of gravity with massive celestial bodies such as planets, stars, and galaxies. Meanwhile, electromagnetic radiation is routinely dismissed as a small-scale phenomenon confined to atoms, molecules, or laboratory instruments. But this comparison is misleading: when the electromagnetic and gravitational fields produced by the same large-scale object are compared directly, the electromagnetic field is overwhelmingly stronger. This prediction anticipates the common objection that electromagnetism is too weak to have measurable effects at large scales and highlights a broader conceptual bias—gravity is assumed to act on cosmic scales, while electromagnetism is confined to short-range interactions and controlled environments.

### PREDICTION 2.

Gravity is known to be approximately  $10^{39}$  times weaker than electromagnetism [7]. This disparity is not anomalous but expected if gravitational effects emerge from electromagnetic radiation. By emitting, absorbing, and redistributing energy, a single fluctuating particle contributes only minimally to overall curvature. But when averaged statistically over countless such particles, the cumulative effect becomes a weak but persistent influence. Though negligible at the level of

individual events, at scales over which gravitational curvature becomes detectable, these interactions collectively generate a smooth, large-scale gradient in field energy—subtle enough to be invisible at the atomic level, yet consistent and extensive enough to give rise to effects that mimic what is traditionally attributed to gravity. The resulting gravitation is so weak compared to electromagnetism that only an enormous aggregation of charged particles can produce a noticeable effect.

## ELECTROMAGNETISM GOVERNS ALL OBSERVABLE MOTION

We define observable motion as motion that can be measured or detected by physical instruments—devices composed of ordinary matter that interact through the electromagnetic field [2]. In classical physics, all recorded measurements of position, velocity, force, energy, and time operate through electromagnetic effects [5]. Electromagnetism is not only the mechanism of observation but also the physical background through which motion occurs [3]. The structure of space and time, as experienced by matter, arises from electromagnetic interaction. Within this framework, gravity, inertia, and contact are not separate forces but unified responses of charged matter to the electromagnetic field under different conditions [2]. In this sense, electromagnetism defines the background of spacetime and serves as the foundation for all observable motion [2].

## ADDRESSING THE NEUTRON OBJECTION: ARE NEUTRONS TRULY NEUTRAL?

As a neutral particle, the neutron may seem—at first glance—to fall outside a framework where electromagnetic fields underlie mechanical effects. However, the neutron has a nonzero, measurable magnetic moment despite having no net electric charge [5], suggesting it is not truly neutral, but a composite structure of internal charged components [1].

From this perspective, the neutron remains compatible with a theory in which all mechanical behavior arises from electromagnetic fields. Its neutrality does not imply an absence of interaction. Instead, its internal field structure continues to couple with surrounding matter, contributing to both inertia and curvature-driven motion. Here, neutrality refers only to net charge—not to the absence of electromagnetic energy.

## THEORETICAL CONSIDERATIONS: NON-BARYONIC MATTER CONTRIBUTIONS

Neutrinos are predicted to possess a nonzero magnetic moment [8], implying a weak electromagnetic interaction, though negligible for most classical considerations. This suggests that even particles traditionally considered non-interacting may still couple to the electromagnetic field under certain conditions. While such particles may eventually be integrated into the framework proposed here, their detailed properties fall outside the present scope.

## SCOPE AND APPLICABILITY: CLASSICAL FRAMEWORK

This paper limits its scope to classical regimes, incorporating classical mechanics, classical electrodynamics, and general relativity in baryonic matter—but outside the atomic nucleus. Phenomena occurring inside atomic nuclei or under extreme high-energy conditions fall outside the domain considered here.

Quantum electrodynamics reveals non-classical field behavior at small scales [5], and the resulting interactions may require modifications to Newtonian gravitational dynamics, as has been proposed in other contexts [9]. At quantum scales, gravitational effects reflect the quantum structure of the electromagnetic field. In that case, quantum-scale interactions would also imply a form of quantum gravity—emerging not as

a separate force, but as a consequence of the quantum structure of electromagnetic fields.

Furthermore, fully incorporating black holes would require extending this framework to account for the complete Schwarzschild solution of general relativity, which is left for future work [3].

The conclusions presented apply strictly to ordinary matter and to the classical behavior of objects composed of it. Within that domain, no evidence demands the existence of any force beyond electromagnetism to explain motion, interaction, or structure—including gravitational effects.

## CONCLUSION

If every classical force acting on ordinary matter is electromagnetic, and if the relativistic structure of spacetime responds to energy, then no independent force is required to explain gravity. What has been labeled “gravitational curvature” is simply the cumulative relativistic effect of electromagnetic field energy acting across extended systems of charge.

This theory does not introduce new particles or equations. It interprets existing physics differently, treating the electromagnetic field as not just a force carrier, but the substance of inertia, curvature, and motion. All measurable quantities—mass, stress, potential, momentum—are defined through electromagnetic response. All observed behavior—resistance, attraction, deceleration, deflection—arises from field interactions.

The electromagnetic field is the spacetime background. It is the physical medium through which motion occurs, the structure through which time and position are defined, and the only field required to describe classical dynamics. There may be other processes at play in domains beyond classical systems. But within the scope of ordinary matter governed by classical mechanics, electrodynamics, and general relativity, no separate gravitational field is necessary. The field already exists. It is electromagnetic.

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