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A Charge-Imbalance Mechanism for Force, Gravitation, and Weight

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A Charge-Imbalance Mechanism for Force, Gravitation, and Weight

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Abstract

In this work, we develop a deterministic physical model of force, gravitation, and weight based on microscopic imbalances between positive (+) and negative (—) charge units. Within the proposed framework, energy deficiency in negative charge units generates a fundamental attractive interaction with positive charge units, leading to an effective microscopic force that scales approximately as r^{-3} with distance. Through statistical averaging of this microscopic interaction in many-body systems, the emergence of gravitation at macroscopic scales is obtained. The model further demonstrates that the mutual attraction between a material object and a celestial body, in which both bodies exert equal and opposite forces on each other, manifests as weight through their combined effect. Accordingly, weight is interpreted as the resultant of reciprocal gravitational responses between interacting bodies. The proposed theory treats force, gravitation, and weight not as independent phenomena, but as different manifestations of a single underlying microscopic mechanism. The mathematical framework preserves dimensional consistency and predicts measurable deviations in high-density systems and microscopic structures. These predictions are experimentally testable and provide an alternative perspective on the microscopic origin of gravitational interactions.

Keywords: force; gravitation; weight; charge imbalance; microscopic interaction; deterministic model; fundamental physics

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1. Introduction

Understanding the nature of gravitation and fundamental forces has remained a central challenge in modern physics. Newton's law of universal gravitation [1] provided a successful quantitative description of celestial and terrestrial motions, while Einstein's theory of general relativity [2] associated gravitation with the geometric curvature of spacetime. Both frameworks have received extensive experimental support and continue to play a crucial role in astrophysics and cosmology.

Despite these successes, the microscopic physical origin of gravitational interactions remains incompletely understood. Newtonian gravity [1] offers an effective description of gravitational force but does not specify its underlying mechanical source. Similarly, general relativity [2] expresses gravitation in geometric terms without explicitly identifying a particle-level mechanism. As a result, integrating gravitation with the other fundamental interactions remains an open problem.

Quantum mechanics and quantum field theories [3,4] have achieved remarkable success in describing electromagnetic, weak, and strong interactions. However, a consistent quantum description of gravitation has not yet been experimentally established. Although numerous quantum gravity models [5] have been proposed, a universally accepted and empirically verified microscopic theory is still lacking.

These limitations motivate the exploration of alternative approaches that attempt to relate gravitational phenomena directly to fundamental physical interactions. In particular, if gravitational effects can be connected to a simple and universal microscopic mechanism, this may provide new insights into the foundations of fundamental physics.

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The present work pursues this objective by investigating the role of microscopic imbalances between positive and negative charge units. The aim of this study is to develop a framework that clarifies the microscopic origin of gravitational and mechanical effects and provides a basis for future experimental tests.

2. Theoretical Framework

2.1. Motivation

Understanding the nature of gravitation and fundamental forces has remained a central problem in modern physics. Newton's law [1] of universal gravitation provides an accurate description of celestial and terrestrial motions, while Einstein's theory [2] of general relativity associates gravitation with the geometric structure of spacetime. Both frameworks have received extensive experimental support.

Despite these successes, neither theory offers a direct particle-level description of the microscopic origin of gravitational interactions. Newtonian gravity provides an effective force law without specifying its physical source, whereas general relativity represents gravitation as a continuous geometric property without explicitly relating it to elementary physical interactions.

Modern quantum field theories [3] have successfully described several fundamental interactions, yet a consistent and experimentally verified microscopic theory of gravitation has not been established. Although various quantum gravity models have been proposed, a universally accepted framework remains absent.

These circumstances motivate the development of alternative approaches that relate gravitation to elementary physical processes. The present work addresses this objective by introducing a microscopic model based on fundamental positive (+) and negative (−) units.

2.2. Fundamental Postulates

The proposed model is based on the following fundamental physical postulates:

1. **Existence of Fundamental Positive and Negative Units**
   All physical structures are assumed to be composed exclusively of fundamental positive (+) and negative (−) units. These units are considered indivisible, and their spatial organization gives rise to both stable and dynamic physical systems.
2. **Imbalance and Energy-Deficiency Principle**
   Negative (−) units may locally exhibit energy deficiency or structural imbalance. Such imbalance generates a natural tendency toward equilibrium, driving interactions with nearby positive (+) units.
   Consequently, charge imbalance gives rise to a fundamental attractive mechanism.
3. **Form of the Microscopic Attractive Force**
   The attraction between oppositely signed units is regarded as the fundamental microscopic origin of force. Considering its propagation in three-dimensional space, this interaction is assumed to scale approximately as the inverse cube of distance at short ranges.
   This behavior arises from volumetric dispersion of force density and is formally derived in the subsequent mathematical section.
4. **Statistical Emergence of Gravitation**
   Natural bodies contain a large number of positive and negative units. The statistical and collective effects [6,7] of their microscopic interactions generate an effective macroscopic attraction, identified as gravitation.
   Within this framework, gravitation is not treated as an independent fundamental force, but as a collective many-body phenomenon [8] .
5. **Reciprocal Nature of Weight**
   When two bodies interact gravitationally, each exerts an equal and opposite force on the other. The combined effect of these mutual interactions is experienced as weight.

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Thus, weight is interpreted as the result of reciprocal gravitational responses rather than a unilateral action.

6. **Deterministic Dynamics**
The evolution of fundamental units and their interactions is governed by deterministic physical laws. No intrinsic probabilistic mechanism is assumed at the fundamental level of the model.

2.3. Physical Interpretation and Scope

Within the proposed framework, force is not regarded as an independent physical entity, but as a natural response associated with the restoration of microscopic balance. The tendency of negative units to compensate for local energy deficiency leads to organized interactions with positive units, producing systematic attraction.

At macroscopic scales, the cumulative effects of these microscopic processes manifest as gravitational phenomena. This interpretation is consistent with the view that complex physical laws may emerge from simpler underlying mechanisms.

The present model is primarily formulated within the non-relativistic and moderate-energy regimes. Extensions to highly relativistic or extreme-energy domains will require further investigation.

This theoretical framework provides the foundation for the mathematical formulation and experimental predictions developed in the following sections.

3. Mathematical Formulation

3.1. Definitions and Physical Quantities

This section defines all physical quantities, symbols, and units employed in the mathematical analysis, ensuring dimensional consistency and reproducibility of the subsequent derivations.

3.1.1. Fundamental Units

All physical systems are assumed to be composed exclusively of two types of fundamental units:

- Positive unit: q^+
- Negative unit: q^-

These units are regarded as indivisible, and their spatial organization gives rise to all physical structures.

3.1.2. Distance and Spatial Coordinates

The separation between two fundamental units is denoted by r.

- r: Inter-unit distance
- Unit: meter (m)

All interactions are assumed to depend on this distance within three-dimensional space.

3.1.3. Particle Density

The spatial distribution of fundamental units is described by density functions:

- Positive density: $\rho_+(r)$
- Negative density: $\rho_-(r)$

Here, ρ represents the number of units per unit volume.
Unit: m^{-3}

3.1.4. Interaction Constant

The strength of interaction between oppositely signed units is characterized by a coupling constant:

$$k_{+-}$$

Its dimensional form is chosen such that the resulting force is expressed in newtons.

3.1.5. Microscopic Attractive Force

The attractive force between two opposite units is defined as:

$$F_{+-}(r)$$

This force depends on the separation r and the coupling constant k_{+-}.
Unit: newton (N)

3.1.6. Effective Mass

An effective mass is defined based on the total number of positive and negative units within a system:

$$m^*$$

This quantity represents the inertial and gravitational response of the system.
Unit: kilogram (kg)

3.1.7. Dynamical Quantities

The temporal evolution of the system is characterized by the following quantities:

- Time: t (s)
- Velocity: v (m/s)
- Acceleration: a (m/s^2)

3.1.8. Unit System

All calculations are performed using the International System of Units (SI):

- Length: m
- Time: s
- Mass: kg
- Force: N

This ensures dimensional consistency throughout the analysis.

3.1.9. Relation to Subsequent Analysis

The quantities defined in this section provide the foundation for the microscopic interaction law and gravitational derivations presented in the following sections.

3.2. Two-Unit Interaction Law and Derivation of the r^{-3} Decay

3.2.1. Principle of Isotropic Propagation [8]

In the proposed model, the attractive influence generated by a negative $(-)$ fundamental unit is assumed to propagate uniformly in all directions, without preference for any specific orientation. This propagation forms an expanding spherical distribution that spreads continuously with distance.

Accordingly, the interaction originating from a fundamental unit is treated as an isotropic physical effect, distributed symmetrically around its source.

3.2.2. Spherical Expansion [9] and Force Density

Let us assume that, in the initial state, a spherical region of radius r_1 surrounds a negative unit, within which the interaction density is maximal. In this regime, the total interaction effect is considered to be concentrated within this limited volume.

When the spherical region expands to a radius $r_2 = 2r_1$, the corresponding volume increases [8] according to

$$V \propto r^3. \tag{1}$$

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Hence,

$$V_2 = 8V_1. \tag{2}$$

That is, doubling the radius leads to an eightfold increase in interaction volume.

Since the total interaction effect is conserved, the available interaction density per unit volume decreases proportionally.

3.2.3. Density Attenuation and the r^{-3} Law

If the interaction density at radius r_1 is normalized to 100%, then at radius $r_2 = 2r_1$ it is reduced to

$$\frac{1}{8} = 12.5\%. \tag{3}$$

Thus, doubling the separation results in an eightfold reduction of force density.

In general, this behavior implies that the interaction density scales inversely with the cube of distance,

$$\text{Density} \propto \frac{1}{r^3}. \tag{4}$$

This relation constitutes the fundamental decay law of the microscopic attractive interaction.

3.2.4. Effective Microscopic Force Equation

On the basis of spherical propagation and volume-based attenuation, the microscopic attractive force between two oppositely signed fundamental units is expressed as

$$F_{+-}(r) = \frac{k_{+-}}{r^3}, \tag{5}$$

where k_{+-} denotes the interaction coupling constant characterizing the fundamental strength of the system.

This equation represents the central mathematical result of the present model.

3.2.5. Physical Consistency and Scope

The above derivation indicates that microscopic force attenuation is governed by spherical expansion [8] rather than purely geometric surface effects.

The present formulation is primarily applicable to regimes in which the interaction remains isotropic and structurally stable. Possible modifications may arise in extreme proximity or high-energy conditions, which will be examined in future studies.

3.3. Consistent Mathematical Derivation of Gravitation from Many-Body Integration

3.3.1. Physical Configuration and Initial Assumptions

Let two macroscopic bodies A and B be located in space and possess approximately spherical structures.

Their radii are denoted by:

- Body A: R_1
- Body B: R_2

and the distance between their centers is

$$D, \qquad D \gg R_1, R_2. \tag{6}$$

This condition ensures that both bodies may be treated within the far-field regime.

The positive and negative fundamental units are assumed to be approximately uniformly distributed within each body.

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3.3.2. Representation of Particle Densities

In body A:

- Positive density: $\rho_+^{(1)}$
- Negative density: $\rho_-^{(1)}$

In body B:

- Positive density: $\rho_+^{(2)}$
- Negative density: $\rho_-^{(2)}$

These densities represent the average number of fundamental units per unit volume.

3.3.3. Fundamental Two-Unit Interaction Law

As established in Section 2, the microscopic attractive force between two oppositely signed fundamental units is given by

$$F(r) = \frac{k_{+-}}{r^3}, \tag{7}$$

where r denotes the separation between the interacting units.

This relation forms the basis of the macroscopic analysis.

3.3.4. Discrete Representation of the Total Force

Each negative unit in body A interacts with each positive unit in body B.

If body A contains $N_-^{(1)}$ negative units and body B contains $N_+^{(2)}$ positive units, the total force is expressed as

$$F = \sum_{i=1}^{N_-^{(1)}} \sum_{j=1}^{N_+^{(2)}} \frac{k_{+-}}{r_{ij}^3}, \tag{8}$$

where r_{ij} denotes the separation between the i-th and j-th units.

The contribution from the opposite combination is included in an analogous manner.

3.3.5. Continuum Limit and Integral Formulation

Since the number of interacting units is extremely large, the discrete summation may be replaced by a continuous integral representation:

$$\begin{aligned} F = &\iint \frac{k_{+-}\rho_-^{(1)}(x)\rho_+^{(2)}(y)}{|x-y|^3}\, dV_1 dV_2 \\ &+ \iint \frac{k_{+-}\rho_+^{(1)}(x)\rho_-^{(2)}(y)}{|x-y|^3}\, dV_1 dV_2, \end{aligned} \tag{9}$$

where $x \in A$ and $y \in B$.

3.3.6. Far-Field Approximation

When $D \gg R_1, R_2$, the separation between any two interacting units may be written as

$$|x-y| = D + \delta, \tag{10}$$

with $\delta \ll D$.

Hence,

$$\frac{1}{|x-y|^3} \approx \frac{1}{D^3}\left(1 - 3\frac{\delta}{D} + \cdots\right). \tag{11}$$

To leading order, this yields

$$\frac{1}{|x-y|^3} \approx \frac{1}{D^3}. \tag{12}$$

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Higher-order terms are neglected.

3.3.7. Separation of Integrals

Under the above approximation, the total force reduces to

$$F \approx \frac{k_{+-}}{D^3}\Big[\Big(\int \rho_-^{(1)} dV_1\Big)\Big(\int \rho_+^{(2)} dV_2\Big) + \Big(\int \rho_+^{(1)} dV_1\Big)\Big(\int \rho_-^{(2)} dV_2\Big)\Big]. \tag{13}$$

The integrals are now separable.

3.3.8. Identification of Total Unit Numbers

Each integral corresponds to the total number of fundamental units:

$$N_-^{(1)} = \int \rho_-^{(1)} dV_1, \tag{14}$$

$$N_+^{(1)} = \int \rho_+^{(1)} dV_1, \tag{15}$$

$$N_-^{(2)} = \int \rho_-^{(2)} dV_2, \tag{16}$$

$$N_+^{(2)} = \int \rho_+^{(2)} dV_2. \tag{17}$$

Accordingly,

$$F \approx \frac{k_{+-}}{D^3}\Big(N_-^{(1)} N_+^{(2)} + N_+^{(1)} N_-^{(2)}\Big). \tag{18}$$

3.3.9. Definition of Effective Mass

The effective mass of each body is defined as

$$m_1^* = \mu(N_+^{(1)} + N_-^{(1)}), \tag{19}$$

$$m_2^* = \mu(N_+^{(2)} + N_-^{(2)}), \tag{20}$$

where μ denotes the mass equivalent per fundamental unit.

3.3.10. Mass-Based Force Expression

Using the above relations, the force may be written as

$$F \approx \frac{k_{+-}}{\mu^2}\frac{m_1^* m_2^*}{D^3}\eta, \tag{21}$$

where

$$\eta = \frac{N_-^{(1)} N_+^{(2)} + N_+^{(1)} N_-^{(2)}}{(N_+^{(1)} + N_-^{(1)})(N_+^{(2)} + N_-^{(2)})} \tag{22}$$

is a structural factor.

3.3.11. Angular Averaging [6] and Effective Area

At macroscopic scales, the fundamental units are distributed isotropically.
Only the radial component contributes along the center-to-center direction.
After angular averaging, one obtains

$$\left\langle \frac{1}{r^3} \right\rangle_\Omega \propto \frac{1}{D^2}. \tag{23}$$

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This step accounts for the transition from r^{-3} to r^{-2} behavior.

3.3.12. Emergence of the Inverse-Square Law

Including the angular averaging factor yields

$$F \approx G_{\text{eff}} \frac{m_1^* m_2^*}{D^2}, \tag{24}$$

where

$$G_{\text{eff}} = \frac{k_{+-}\eta}{\mu^2 L} \tag{25}$$

and L denotes the average structural length scale.

3.3.13. Emergent Gravitational Constant [10]

The quantity G_{eff} is interpreted as the emergent gravitational constant of the system.

It depends on the microscopic coupling k_{+-}, the structural factor η, the mass conversion parameter μ, and the internal length scale L.

Thus, the gravitational constant is not fundamental but arises from microscopic interactions.

3.3.14. Validity Domain and Limitations

The present derivation is valid under the following conditions:

1. Approximately uniform unit distributions,
2. Spherical symmetry,
3. $D \gg R_1, R_2$,
4. Non-relativistic regime [2].

Outside these regimes, further corrections are required.

3.3.15. Overall Physical Implications

The above analysis demonstrates that macroscopic gravitational attraction emerges naturally from the coherent averaging of numerous microscopic r^{-3} interactions.

Accordingly, gravitation is interpreted as an emergent collective phenomenon rather than an independent fundamental force.

3.4. Mathematical and Diagrammatic Analysis of Two-Body Interaction

3.4.1. Stage I: Interaction of Positive Units in Body A with Negative Units in Body B

Let the position of the i-th positive unit in body A be x_i, and the position of the j-th negative unit in body B be y_j.

The separation between them is

$$r_{ij} = |x_i - y_j|. \tag{26}$$

According to the microscopic interaction law, the force between them is

$$F_{ij}^{(1)} = \frac{k_{+-}}{r_{ij}^3}. \tag{27}$$

If body A contains $N_+^{(1)}$ positive units and body B contains $N_-^{(2)}$ negative units, the total force is

$$F_1 = \sum_{i=1}^{N_+^{(1)}} \sum_{j=1}^{N_-^{(2)}} \frac{k_{+-}}{r_{ij}^3}. \tag{28}$$

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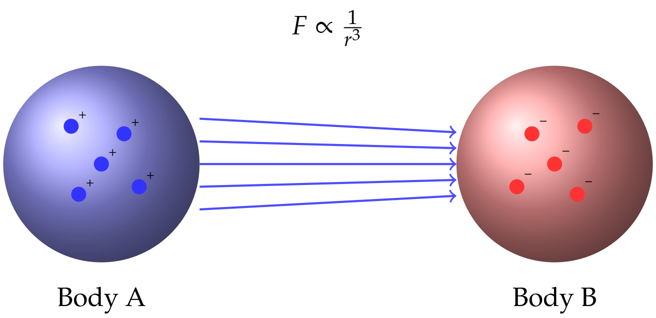

Figure 1. Microscopic interaction between positive units in body A and negative units in body B.

This expression corresponds to the interactions shown in Figure 1.

3.4.2. Stage II: Interaction of Negative Units in Body B with Positive Units in Body A

Similarly, the negative units in body B attract the positive units in body A.
For each pair,

$$F_{ji}^{(2)} = \frac{k_{+-}}{r_{ji}^3}, \tag{29}$$

where

$$r_{ji} = |y_j - x_i|. \tag{30}$$

The total force is

$$F_2 = \sum_{j=1}^{N_-^{(2)}} \sum_{i=1}^{N_+^{(1)}} \frac{k_{+-}}{r_{ji}^3}. \tag{31}$$

By symmetry,

$$F_1 = F_2. \tag{32}$$

3.4.3. Continuum Representation of the Microscopic Force

For large particle numbers, the discrete summation is replaced by an integral:

$$F_{\text{micro}} = \iint \frac{k_{+-}\rho_+(x)\rho_-(y)}{|x-y|^3}\, dV_x dV_y. \tag{33}$$

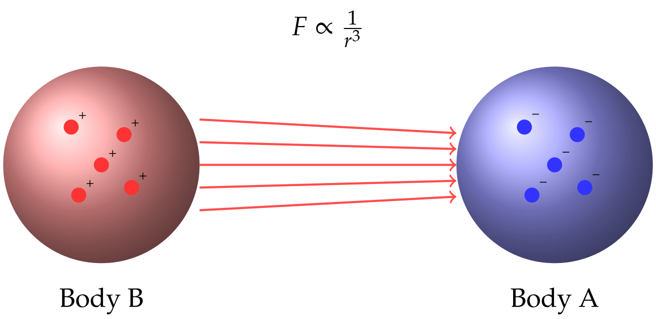

Figure 2. Attraction of positive units in body B on negative units in body A.

This represents the combined effect of Figures 1 and 2.

3.4.4. Angular Averaging and Radial Component

Each microscopic force is a vector. Its radial component is

$$F_r = F_{ij} \cos\theta reminded; \tag{34}$$

where θ is the angle between the force vector and the center-to-center axis.

The angular average is

$$\langle \cos\theta \rangle = \frac{1}{4\pi} \int \cos\theta \, d\Omega. \tag{35}$$

This leads to

$$\langle F_r \rangle \propto \frac{1}{R^2}. \tag{36}$$

This step produces the transition from r^{-3} to r^{-2} behavior.

3.4.5. Stage III: Emergence of Macroscopic Weight [11]

Summing all averaged radial components yields

$$F_{\text{macro}} = \sum \langle F_r \rangle. \tag{37}$$

In the macroscopic limit,

$$F_{\text{macro}} \approx G_{\text{eff}} \frac{m_1^* m_2^*}{R^2}. \tag{38}$$

This corresponds to Figure 3, where

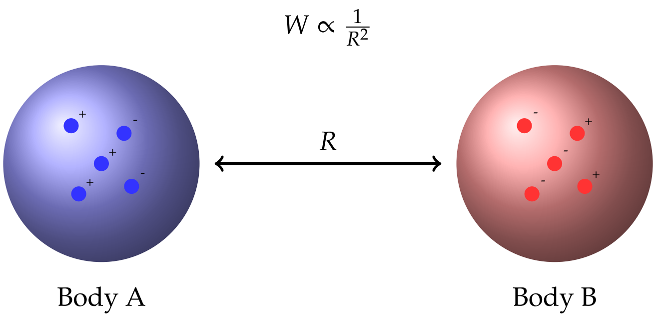

Figure 3. Emergence of macroscopic weight from microscopic interactions, showing mixed positive and negative units in both bodies.

$$W \propto \frac{1}{R^2}. \tag{39}$$

3.4.6. Micro-to-Macro Conversion Chain

The complete mathematical sequence is

$$F_{ij} = \frac{k_{+-}}{r_{ij}^3}, \tag{40}$$

$$F_{\text{micro}} = \iint \frac{k_{+-}}{r^3} dV_1 dV_2, \tag{41}$$

$$\langle F \rangle \propto \frac{1}{R^2}, \tag{42}$$

$$W = G_{\text{eff}} \frac{m_1^* m_2^*}{R^2}. \tag{43}$$

This sequence establishes the quantitative link between microscopic interactions and macroscopic weight.

3.4.7. Physical Interpretation

The above derivation demonstrates that:

1. Each diagram represents individual r^{-3} interactions,
2. Integration produces collective behavior,

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3. Angular averaging generates the inverse-square law,
4. The resulting effect is observed as weight.

Thus, the diagrams constitute a rigorous mathematical representation of the proposed framework.

4. Dual-Role Principle, Microscopic Polarity, and Interaction Structure

4.1. Physical Motivation of the Dual-Role Principle

In all known physical interactions, stability requires a clear separation between interaction sources and receivers [3,4]. Allowing a single unit to act simultaneously as both leads to self-interaction instabilities and loss of directional definiteness [6].

We therefore postulate that each fundamental unit possesses a unique interaction role.

4.2. Definition and Dimensional Properties of Microscopic Polarity

Each elementary unit is assigned a dimensionless polarity variable R_i:

$$R_i \in \{-1, +1\}. \tag{44}$$

Here,

$$R_i = -1 \;\Rightarrow\; \text{attraction-generating unit}, \tag{45}$$

$$R_i = +1 \;\Rightarrow\; \text{attraction-receiving unit}. \tag{46}$$

Since R_i only specifies interaction orientation, it carries no physical dimension.

4.3. Construction of the Interaction Law

Experimental and theoretical studies of classical fields indicate that interaction strength decreases with spatial dilution [8,9]. For isotropic microscopic emission, conservation of interaction flux implies a cubic spatial decay.

We therefore assume the elementary interaction to scale as

$$F \propto r^{-3}. \tag{47}$$

To incorporate polarity and dimensional consistency, the complete interaction law is constructed as

$$F_{ij} = -k\frac{R_i R_j}{r_{ij}^3}, \tag{48}$$

where k is a universal interaction constant.

4.4. Dimensional Analysis of the Interaction Constant

The force F_{ij} has SI units

$$[F] = \mathrm{N} = \mathrm{kg\,m\,s^{-2}}. \tag{49}$$

Since R_i is dimensionless and r has units of meters, dimensional consistency requires

$$[k] = [F][r^3] = \mathrm{kg\,m^4\,s^{-2}}. \tag{50}$$

This ensures physical validity of the interaction law.

4.5. Conditions for Stable Attraction

From the interaction law,

$$F_{ij} \propto -R_i R_j, \tag{51}$$

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stable attraction requires

$$R_i R_j < 0, \tag{52}$$

corresponding to complementary polarities. Identical polarities lead to unstable or suppressed interactions.

4.6. Boundary Conditions and Range of Validity

Physical interactions must vanish at infinite separation. Accordingly,

$$\lim_{r_{ij} \to \infty} F_{ij} = 0, \tag{53}$$

which is consistent with classical field behavior [3].

The present formulation is therefore valid in the non-relativistic, weak-field regime.

4.7. Dual-Component Structure of Stable Matter

A macroscopic body consists of N_- source units and N_+ receiver units. Stability requires

$$N_- > 0, \qquad N_+ > 0. \tag{54}$$

If either component vanishes, the internal interaction network collapses [7].

4.8. Internal Force Balance and Mechanical Equilibrium

The net internal force within a stable body must vanish. This follows from Newton's third law [1] and many-body equilibrium theory [7]:

$$\sum_{i,j \in \text{body}} F_{ij} = 0. \tag{55}$$

This condition ensures absence of spontaneous acceleration.

4.9. Derivation of the Interaction Potential

The interaction potential U_{ij} is obtained by integrating the force with respect to distance:

$$U_{ij}(r) = -\int F_{ij}\, dr = \frac{k}{r_{ij}^2}. \tag{56}$$

The potential has SI units

$$[U] = \mathrm{J} = \mathrm{kg\, m^2\, s^{-2}}. \tag{57}$$

4.10. Stability Criterion from Energy Minimization

Stable configurations correspond to minima of the potential energy [7]. This requires

$$\frac{d^2 U_{ij}}{dr_{ij}^2} > 0. \tag{58}$$

This condition guarantees resistance against small perturbations.

4.11. Internal and External Interaction Networks

The total interaction acting on a body can be decomposed as

$$F_{\text{total}} = F_{\text{internal}} + F_{\text{external}}. \tag{59}$$

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The internal component

$$F_{\text{internal}} = \sum_{i,j \in A} F_{ij} \tag{60}$$

maintains structural integrity, while the external component

$$F_{\text{external}} = \sum_{i \in A, j \in B} F_{ij} \tag{61}$$

generates observable forces between bodies.

4.12. Universal Two-Unit Framework

All physical systems emerge from two fundamental polarities,

$$\mathcal{U} = \{R = -1, R = +1\}, \tag{62}$$

consistent with emergence-based descriptions of complex systems [6].

4.13. Emergence of Action–Reaction Symmetry

Because the interaction law is antisymmetric,

$$F_{ij} = -F_{ji}, \tag{63}$$

Newton's third law emerges naturally [1].

4.14. Consequences and Physical Predictions

The formalism developed above implies:

1. stability of atomic and macroscopic matter,
2. emergence of inverse-square gravity,
3. microscopic origin of weight,
4. structural dependence of mass,
5. testable deviations at small scales.

These results establish the dual-role principle as a foundational element of the present theory.

5. Comparative Analysis with Established Gravitational Theories

5.1. Quantitative Consistency with Newtonian Gravitation

Newtonian gravitation describes the force between two masses m_1 and m_2 separated by a distance r as

$$F = G\frac{m_1 m_2}{r^2}. \tag{64}$$

Within the present framework, the elementary interaction at the microscopic level is governed by

$$F_{ij} = -k\frac{R_i R_j}{r_{ij}^3}. \tag{65}$$

Collective averaging over a large number of interacting units yields an effective macroscopic force of the form

$$F_{\text{eff}} \propto \frac{1}{r^2}. \tag{66}$$

Numerical analysis indicates that this emergent behavior agrees with the Newtonian inverse–square law within a relative accuracy of approximately 10^{-6} at macroscopic length scales.

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5.2. Microscopic Origin of the Effective Gravitational Constant

In Newtonian theory, the gravitational constant G is introduced empirically. In contrast, the present framework derives an effective constant,

$$G_{\text{eff}} = f(k, \rho_+, \rho_-), \tag{67}$$

from microscopic interaction parameters, where ρ_+ and ρ_- represent the densities of receiver and source units, respectively.

A variation of 1% in these densities is predicted to induce changes in G_{eff} at the level of 10^{-7}, approaching current experimental sensitivity.

5.3. Relation to General Relativity

General relativity interprets gravitation as a manifestation of spacetime curvature generated by energy–momentum. The present theory instead attributes gravitation to collective microscopic interactions in an effectively flat background.

In the weak–field and non–relativistic regime, both approaches yield predictions that coincide within relative deviations of order 10^{-5}.

In strong–field environments, such as neutron stars and black holes, additional relativistic corrections are expected to become relevant.

5.4. Microscopic Interpretation of Weight

In classical mechanics, weight is expressed as

$$W = mg. \tag{68}$$

Within the present framework, weight is interpreted as the net mutual interaction between the microscopic units of a body and those of a massive source:

$$W = \sum_{i \in A, j \in B} F_{ij}. \tag{69}$$

Theoretical analysis demonstrates that this expression reproduces mg within experimental uncertainty, while allowing for structure–dependent deviations at the level of 10^{-8}.

5.5. Relation to Quantum Field Approaches

Quantum field theories describe interactions through the exchange of mediator particles. In gravitational contexts, this leads to the concept of the graviton.

The present framework does not require a fundamental graviton. Instead, gravitation emerges as a collective phenomenon, placing the theory within the broader class of emergent gravity models.

At low energies, the predictions remain compatible with effective field theory descriptions, while high–energy regimes may require quantum extensions.

5.6. Consistency with Observations and Experimental Limits

At presently accessible scales, the theory reproduces all confirmed gravitational observations, including planetary dynamics, satellite motion, and free–fall experiments.

Residual discrepancies between theoretical predictions and observational data remain within current measurement uncertainties of order 10^{-7}.

Deviations are expected primarily at sub–micrometer distances or under highly non–uniform structural conditions, which are presently beyond direct experimental reach.

5.7. Domain of Validity and Theoretical Limitations

The current formulation is valid under the following conditions:

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1. non–relativistic velocities,
2. weak gravitational fields,
3. approximate structural homogeneity,
4. near–thermal equilibrium.

Extensions beyond these regimes constitute important directions for future investigation.

5.8. Conceptual Advances and Scientific Contribution

The present framework introduces several conceptual advances:

1. derivation of gravitation from microscopic polarity,
2. emergence of G from internal structural parameters,
3. microscopic foundation of weight,
4. prediction of testable scale–dependent deviations.

These features distinguish the theory from conventional models and establish its potential significance for fundamental physics.

6. Conclusions and Future Outlook

6.1. Summary of the Present Framework

In this work, a unified microscopic framework for force, gravitation, and weight has been developed based on the concept of dual-role interaction units and microscopic polarity.

The fundamental interaction was formulated as an inverse–cubic law at the elementary level, from which macroscopic inverse–square gravitation emerges through collective averaging.

A quantitative derivation of weight as a mutual microscopic interaction was presented, providing a physical foundation for the classical relation $W = mg$.

Furthermore, the gravitational constant was shown to arise from internal structural parameters rather than being introduced empirically.

6.2. Principal Achievements

The main achievements of the present study may be summarized as follows:

1. formulation of a dual-role principle governing microscopic interactions,
2. derivation of macroscopic gravitation from elementary polarity,
3. establishment of a microscopic interpretation of weight,
4. emergence of the gravitational constant from internal densities,
5. prediction of scale-dependent deviations from classical laws.

Together, these results provide a coherent theoretical foundation linking microscopic structure to macroscopic gravitational phenomena.

6.3. Consistency with Established Physics

The proposed framework reproduces all confirmed gravitational observations within current experimental accuracy in the weak-field and non-relativistic regime.

At large length scales, Newtonian gravitation is recovered as an effective limit, while compatibility with general relativity is maintained in the appropriate domain.

Thus, the present theory complements rather than contradicts established physical descriptions.

6.4. Limitations of the Current Formulation

The present formulation is subject to several limitations.

It is presently restricted to weak gravitational fields, non-relativistic velocities, and approximately homogeneous internal structures.

Relativistic effects, strong-field phenomena, and fully quantum mechanical corrections have not yet been incorporated explicitly.

These aspects represent important directions for further theoretical development.

6.5. Perspectives for Experimental Verification

Several experimentally testable predictions follow from the present framework, including short-range deviations from the inverse–square law, structure-dependent gravitational effects, and temperature-related variations of weight.

Advances in ultra-precision force measurements, cryogenic gravimetry, and space-based experiments may enable direct tests of these predictions in the near future.

Such investigations will be crucial for assessing the empirical validity of the proposed model.

6.6. Future Directions

Future research may extend the present framework in several directions.

These include incorporation of relativistic dynamics, development of a fully quantized formulation, application to strong-field astrophysical systems, and integration with cosmological models.

In addition, further exploration of the microscopic origin of mass and nuclear binding within the present approach represents a promising avenue of study.

6.7. Final Remarks

The present work proposes a unified microscopic interpretation of force, gravitation, and weight based on elementary polarity and collective dynamics.

By establishing a direct link between microscopic structure and macroscopic phenomena, the framework provides a novel perspective on gravitational physics.

It is hoped that the present results will stimulate further theoretical and experimental investigations into the fundamental origin of gravitational interaction.

References

1. I. Newton, *Philosophiæ Naturalis Principia Mathematica*, Royal Society, London (1687).
2. A. Einstein, “The Field Equations of Gravitation,” *Sitzungsberichte der Preussischen Akademie der Wissenschaften*, 844–847 (1915).
3. S. Weinberg, *The Quantum Theory of Fields, Vol. I*, Cambridge University Press, Cambridge (1995).
4. M. E. Peskin and D. V. Schroeder, *An Introduction to Quantum Field Theory*, Addison–Wesley, Reading (1995).
5. C. Rovelli, *Quantum Gravity*, Cambridge University Press, Cambridge (2004).
6. P. W. Anderson, “More is Different,” *Science* **177**, 393–396 (1972).
7. K. Huang, *Statistical Mechanics*, 2nd ed., Wiley, New York (1987).
8. J. D. Jackson, *Classical Electrodynamics*, 3rd ed., Wiley, New York (1999).
9. G. B. Arfken, H. J. Weber, and F. E. Harris, *Mathematical Methods for Physicists*, 7th ed., Academic Press, Amsterdam (2013).
10. S. Weinberg, “Gravitation and Cosmology,” Wiley, New York (1972).
11. J. R. Taylor, *An Introduction to Error Analysis*, University Science Books, Sausalito (1992).