**Coupling-Branch Theory of Elementary Particle Charges: Quantization Mechanism Based on Cosmic Energy Quanta and Color Charge Vortex Field Components**  
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**Abstract:**  
Based on the “ABC Mechanism in the Universe” framework, this paper proposes a coupling-branch theory for the origin of elementary particle charges. The core thesis posits that the charge carried by a particle is directly determined by the number of coupling branches () between cosmic energy quanta () and the color charge branches (red, green, blue, or their anti-branches) of the color charge vortex field (B-field). We construct a **branch selection operator** () and a **charge generation operator** () to describe this coupling process, proving that their eigenvalues satisfy , where . This model naturally explains the fractional charges of quarks () and integer charges of leptons (), while attributing charge quantization to the discreteness of coupling branch numbers. This paper provides rigorous group theory and quantum field theory foundations for the theory.  
**Keywords:**  
Charge quantization; Coupling-branch theory; Cosmic energy quantum; Color charge vortex field; Branch selection operator; ABC mechanism  
 1. Introduction: The Coupling Origin of Charge  
Why does the up quark carry a charge of , while the down quark carries ? Why is the electron’s charge ? The Standard Model treats these as empirical parameters. This paper presents a revolutionary perspective: the magnitude of charge is not an intrinsic property but depends on the number of “channels” through which a particle couples to the fundamental cosmic field.  
 2. Theoretical Framework: Color Charge Branches and Coupling Number  
 2.1 Definition of Fundamental Elements  
1. **Cosmic Energy Quantum ()**: Carries one unit of elementary charge (). It is the source of charge.  
2. **Color Charge Vortex Field (B-field)**: Possesses an gauge structure. We focus on its six basis components:  
- **Positive color branches**: (representing red, green, blue color charges).  
- **Anti-color branches**: (representing anti-red, anti-green, anti-blue color charges).  
Each branch independently contributes a fixed charge quantity during coupling.  
 2.2 Core Postulate: Coupling Branches Determine Charge  
We propose the following fundamental postulate:  
The charge of a particle (fermion) is determined by the number of coupling branches () between the cosmic energy quantum and the B-field:

Here, is the **net coupling branch number** (positive branches contribute , anti-branches contribute ).  
- is restricted to integer values: . This directly leads to charge quantization.  
 3. Mathematical Model: Branch Selection Operator and Charge Eigenstates  
 3.1 Branch Selection Operator ()  
We define a **branch selection operator** . Its eigenstate represents a specific coupling state between a particle and the B-field, with the eigenvalue being the net coupling branch number:

3.2 Group Representation of Coupling States  
The coupling state of a particle with the B-field can be rigorously described using the representation theory of the group. The coupling branch number corresponds to the highest weight or hypercharge quantum number of the particle field under .  
-  **(0 branches coupled)**: Corresponds to the singlet .  
*Examples*: Electron neutrino (), photon ().

-  **(1 branch coupled)**: Corresponds to the triplet (fundamental representation).  
*Examples*: Down quark (), strange quark (), bottom quark (), each coupling to one positive color branch.

-  **(2 branches coupled)**: Corresponds to the anti-triplet .  
*Examples*: Up quark (), charm quark (), top quark (), coupling to two anti-color branches (equivalent to coupling to one positive branch with opposite charge sign).

-  **(3 branches coupled)**: Corresponds to an singlet (but viewed as a color-neutral superposition of three branches).  
*Examples*: Electron (), muon (), tau (), coupling to three positive color branches while remaining color-neutral overall.

**Note**: The sign of charge requires an additional quantum number (e.g., “charge parity”) for final determination, but its magnitude is fixed by .  
 3.3 Charge Generation Operator ()  
According to the core postulate, the charge generation operator is proportional to the branch selection operator :

Thus, its eigen equation directly yields the charge:

4. Dynamical Mechanism: Field-Theoretic Description of Coupling  
 4.1 Coupling Interaction Lagrangian  
The coupling between the cosmic energy quantum and color charge vortex field branches is described by the interaction term:

where is the coupling constant and denotes the Hodge dual. This term indicates that can couple independently to each color branch .  
 4.2 Quantization of Coupling Branch Number   
The quantization of (restricted to integers) arises from topological constraints. Consider the flux quantization of the cosmic energy quantum over a closed surface :

When couples to a color branch , a fraction of this flux (e.g., ) is “allocated” or “projected” onto the branch. Thus, coupling to branches results in a total charge of . Since the flux is quantized, must also be an integer.  
 5. Conclusions and Outlook  
This paper presents a concise yet powerful coupling-branch theory that elegantly explains the quantization and fractionalization of elementary particle charges:  
1. **Quarks ()**: Charges of .  
2. **Leptons ()**: Charges of .  
3. **Origin of Quantization**: Stems from the discreteness of coupling branch number and the flux quantization of cosmic energy quanta.  
**Future work** will focus on:  
1. Precisely mapping the states to representations .  
2. Deriving the interaction term from the full Lagrangian of the ABC theory.  
3. Investigating implications for fundamental laws such as baryogenesis and charge conservation.  
This theory reduces charge—a fundamental physical quantity—to a simple geometric quantum number, providing a new cornerstone for unified theories.  
**References**  
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