Constitutive Mechanics of the Vacuum

Companion Paper VII

Mechanical Tunneling: Evanescent Stress, Impedance Barriers, and Nuclear Decay

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Abstract

Quantum tunneling is traditionally interpreted as a particle probabilistically traversing a classically forbidden region. In this companion paper, we demonstrate that tunneling phenomena arise naturally when wave propagation is treated within a continuous elastic medium possessing spatially varying impedance. Within the Constitutive Vacuum (CV) framework, tunneling corresponds to evanescent stress penetration and partial impedance transmission, not particle traversal. By applying standard elastic wave theory to finite stiffness barriers, we recover the familiar exponential attenuation, transmission coefficients, and decay laws of quantum mechanics. Alpha decay is reinterpreted as leakage from a mechanically resonant nuclear cavity. No intrinsic randomness or nonlocal behavior is required.

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1. Introduction

1.1 The Tunneling Paradox

In conventional quantum mechanics, tunneling appears paradoxical: particles are observed to cross potential barriers despite possessing insufficient classical energy. This behavior is often presented as irreducibly probabilistic and non-mechanical.

However, **tunneling is ubiquitous in classical wave systems**—including acoustics, optics, and elasticity—whenever waves encounter impedance mismatches. The CV framework treats quantum systems as wave–defect structures embedded in a physical medium, making tunneling a natural and expected phenomenon.

1.2 Scope and Claims

This paper makes the following limited claims:

- Tunneling corresponds to **evanescent stress fields**, not particle motion
- Transmission probabilities arise from **impedance matching**
- Nuclear decay reflects **leaky resonator dynamics**
- Quantum tunneling requires no violation of classical causality

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2. Evanescent Stress in Elastic Media

2.1 Barrier as Impedance Mismatch

Consider a one-dimensional shear wave incident on a region of increased stiffness S. Within the barrier region $0 \leq x \leq w$, the wave equation admits exponentially decaying solutions:

$$u_{II}(x) = Ce^{-\kappa}$$

where:

- $u(x)$is the lattice displacement
- $\kappa$is the attenuation constant
- No net energy flow occurs inside the barrier

The wave does not propagate; it **stores elastic strain energy**.

2.2 Physical Interpretation

This evanescent field is analogous to:

- Reactive power in electrical circuits
- Near-field electromagnetic penetration
- Acoustic decay in waveguides below cutoff

No material entity traverses the barrier. Only **stress penetration** occurs.

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3. Transmission Through a Finite Barrier

3.1 Boundary Conditions

At each interface, continuity of displacement and stress requires:

$$u_I = u_{II}, S_I \frac{du_I}{dx} = S_{II} \frac{du_{II}}{dx}$$

Solving for a finite barrier yields the energy transmissibility:

$$T \approx \frac{16k^2\kappa^2}{(k^2+\kappa^2)^2} e^{-2\kappa w}$$

for $\kappa w \gg 1$.

3.2 Relation to Quantum Mechanics

This expression is mathematically identical to the quantum tunneling probability derived from the Schrödinger equation. Within the CV framework:

- $T$is **stress transmission efficiency**
- Exponential suppression reflects **impedance mismatch**
- “Probability” is an ensemble-level diagnostic

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4. Alpha Decay as a Leaky Resonator

4.1 The Nucleus as an Acoustic Cavity

In Companion Papers III and VI, the nucleus was identified as a **stress-focused cavitated core**—a resonant elastic cavity embedded in the vacuum lattice.

An alpha particle corresponds to a localized **breathing-mode excitation** trapped within this cavity.

4.2 Escape Mechanism

Each oscillation of the alpha mode impinges on the surrounding stiff lattice (the Coulomb barrier). This generates an evanescent stress field in the barrier region.

Because the barrier is finite, a small fraction of this stress leaks through, allowing the mode to escape.

4.3 Derivation of the Geiger–Nuttall Law

The attenuation constant is given by:

$$\kappa(r) = \frac{\sqrt{2m[V(r) - E]}}{\hbar}$$

where $V(r)$is the Coulomb-induced stiffness enhancement.

The total attenuation (Gamow factor) is:

$$G = 2\int_R^b \kappa(r)\, dr$$

The decay rate is:

$$\lambda = f_{\text{coll}} e^{-G}$$

Taking logarithms reproduces the empirical Geiger–Nuttall law:

$$\ln\, \lambda = \ln\, f_{\text{coll}} - G$$

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5. No Randomness, No Superluminality

5.1 Determinism and Ensemble Behavior

Each alpha decay event is deterministic at the mechanical level, but sensitive to microscopic conditions. Apparent randomness arises from ensemble averaging, consistent with CMV-III.

5.2 Causality Preservation

- Evanescent fields do not transport energy
- Energy propagation remains limited by shear-wave speed c

- No signal or influence travels faster than allowed

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6. Relation to Other Quantum Phenomena

Within the CV framework:

Phenomenon	Mechanical Interpretation
Tunneling	Evanescent stress transmission
Barrier	Stiffness/impedance gradient
Probability	Transmission efficiency
Decay	Resonator leakage

Tunneling is revealed as **wave mechanics in a structured medium**, not quantum magic.

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7. Limitations

This paper does **not** claim:

- Elimination of quantum formalism
- Control of decay events
- Replacement of nuclear models

It provides a **mechanical substrate** for well-established results.

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8. Conclusion

Quantum tunneling emerges naturally when wave propagation is treated in a continuous elastic medium with spatially varying impedance. Evanescent stress fields store energy within barriers, and finite barrier thickness permits partial transmission. Alpha decay is thus understood as leakage from a resonant cavity, governed by classical wave mechanics. This interpretation preserves all quantitative predictions of quantum mechanics while restoring physical continuity and causality within the Constitutive Vacuum framework.

References

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