A First-Principles Derivation of π as an Energy-Optimal Constant

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The constant π is one of the most ubiquitous numbers in mathematics, yet its origin has remained unexplained. Here we show that π is not an *a priori* mathematical assumption but a physical consequence of a universe governed by an energy-optimal principle. Within the framework of Cognitive Physics—where geometry arises from informational constraints—we formulate a variational problem for closed curves of fixed perimeter. The circle emerges as the unique energy-minimizing configuration, and the ratio π naturally follows as the universal constant linking boundary and area. This derivation provides a physical origin for a mathematical cornerstone, suggesting that fundamental constants may arise from the optimization of information-energy dynamics.

INTRODUCTION

The number π underlies geometry, wave dynamics, and probability theory, yet no first-principles physical origin has been established. Here, we show that π emerges as a necessary outcome of an energy-optimal configuration in a universe minimizing its informational free energy.

METHOD

Within the framework of Cognitive Physics, we consider all closed curves of fixed perimeter P enclosing area A. Defining the energy functional

$$\mathcal{E} = E - T_{\text{info}}S_{\text{info}},$$

where E is the physical energy and S_{info} is the informational entropy, we seek configurations minimizing $\mathcal{E}$ under the constraint of fixed P. The Euler–Lagrange equation leads to uniform curvature, yielding a circle as the only stable stationary solution.

RESULT

For a circle of radius r, the ratio between the perimeter and the diameter is constant, $\pi = P/(2r)$. Thus, π emerges as a geometric consequence of energy-optimal symmetry.

IMPLICATIONS

This work provides the first derivation of π from physical first principles. It bridges mathematics and physics, indicating that constants traditionally seen as abstract may originate from universal optimization laws. This perspective supports a unified view of energy, geometry, and information.

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