HOK Physics Kernel v0.1:
The Rosetta Stone

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1 Axiomatic Definition and L1 Mapping

1.1 The Substrate: A Dynamic Graph G

HOK postulate. The physical universe is not introduced as a continuum manifold, but as a discrete information-processing substrate: a family of directed, weighted graphs evolving in an emergent update parameter.

Formally, let

$$\mathcal{G}(\tau) = (N, E, \omega(\tau)) \tag{1.1}$$

denote the graph at update parameter τ, where

- N is a (possibly countable) set of nodes (events or local states),
- $E \subseteq N \times N$ is a set of directed edges (causal or informational links),
- $\omega : E \times \mathbb{R} \to \mathbb{R}^+$ assigns a non-negative weight $\omega(e, \tau)$ to each edge e at "time" τ, interpreted as capacity or tension magnitude.

We write $\Psi(\tau)$ for a complete configuration of node and edge states on $\mathcal{G}(\tau)$; the set of all such configurations is denoted by Ω.

Standard-physics analogues (L1).

- In approaches to quantum gravity such as causal dynamical triangulations, a discrete structure underlies the effective spacetime manifold.
- In quantum many-body and holographic constructions, lattice or tensor-network descriptions play a similar role as discrete substrates.

HOK does not identify itself with any specific proposal, but adopts similar graph-based kinematics as its ontic starting point.

1.2 Five Primitives: L1 Dictionary

We now define the five HOK primitives and map them to standard mathematical objects and physical analogues. At the L1 level, this is a dictionary, not yet a structural equivalence.

Symbol	HOK concept	L1 definition / analogue
F	Field	The collection of all admissible configurations Ω on $\mathcal{G}$; the state field over the g
C	Container	A subgraph $C = (N_C, E_C)$ with $N_C \subseteq N$, $E_C \subseteq E$, that remains stable (up to s
B	Boundary	The interface between a container C and its complement. In a directed graph,
V	Vector	An oriented path or coarse-grained flow of information on $\mathcal{G}$, given by an order
T	Tension	A functional $T : \Omega \to \mathbb{R}$ assigning a real-valued cost or stress to each global con

Heuristic analogues in standard physics.

- F corresponds to the set of all field configurations in classical or quantum field theory.

- A container C plays the role of a particle, bound system, or thermodynamic system, depending on scale.
- A boundary B resembles a system interface, an event horizon, or a Markov blanket in stochastic dynamics.
- A vector V is analogous to momentum, current, or a force-carrying trajectory.
- Tension T stands in for quantities such as action S, potential energy, or free energy, depending on context.

1.3 Core Dynamics: Tension-Driven Evolution

At the kernel level, HOK postulates that the dynamics of the universe can be expressed as the evolution of configurations $\Psi(\tau) \in \Omega$ driven by a tension functional $T[\Psi]$.

Definition 1.1 (Tension functional)**.** *A tension functional is a map*

$$T : \Omega \to \mathbb{R}, \qquad \Psi \mapsto T[\Psi], \tag{1.2}$$

interpreted as the global cost or stress associated with the configuration Ψ of $\mathcal{G}$.

Postulate 1.1 (Gradient-flow form in the continuum limit)**.** *In an appropriate coarse-grained and continuum limit of the discrete update rule for Ψ, the evolution can be approximated by a gradient flow on the tension landscape:*

$$\frac{d}{d\tau}\Psi(\tau) = -k\,\nabla_{\Psi} T[\Psi(\tau)], \tag{1.3}$$

for some proportionality constant $k > 0$, where $\nabla_{\Psi} T$ denotes a formal gradient of T with respect to Ψ in the effective configuration space.

This postulate is intended as an L2-base assumption: in later sections we show that, under additional assumptions on T and on the effective configuration manifold, the gradient-flow form reproduces the principle of least action and standard Lagrangian mechanics in the appropriate regime.

1.4 Dimensional Consistency and the Form of G_{eff}

Early red-team feedback pointed out that a naive relation of the form $G \sim c^3/\hbar$ is dimensionally inconsistent, lacking a factor of length squared. HOK incorporates this by introducing a fundamental length scale l_* associated with the granularity of the graph $\mathcal{G}$.

Postulate 1.2 (Structural form of effective Newton constant)**.** *There exists a characteristic lattice scale l_* (for example the edge spacing of $\mathcal{G}$ in an appropriate embedding) such that the effective Newton constant takes the structural form*

$$G_{\mathit{eff}} \approx \eta\,\frac{c^3\, l_*^2}{\hbar}, \tag{1.4}$$

where η is a dimensionless constant of order unity encoding details of the kernel microstructure.

Dimensional check.

$$[c] = LT^{-1}, \qquad [\hbar] = ML^2T^{-1}, \qquad [l_*] = L.$$

Then

$$\left[\frac{c^3 l_*^2}{\hbar}\right] = \frac{L^3T^{-3}\cdot L^2}{ML^2T^{-1}} = L^3M^{-1}T^{-2} = [G],$$

matching the dimensions of Newton's constant.

At this stage, Postulate 1.2 is not an L3 derivation of the numerical value of G. It states a structural expectation: once a fundamental lattice scale l_* and an effective action quantum $\hbar$ are present, a natural way for a long-range coupling with dimensions of G to emerge is via a combination of the form $c^3 l_*^2/\hbar$, up to a dimensionless factor η. The L3 program is to compute η and relate l_* to observable scales within a concrete kernel model.

2 Classical Mechanics as Coarse-Grained Tension Dynamics

2.1 Setup: A Single Container Degree of Freedom

Consider a container C whose effective state can be described, after coarse-graining, by a single coordinate $q(t)$ along one spatial dimension. At the kernel level, the state of C is encoded in many nodes and edges; we assume that in the macroscopic limit these can be summarized by $q(t)$ and possibly a finite number of additional slow variables.

We introduce an effective tension density $L(q, \dot{q}, t)$ such that the total tension associated with a history $q(t)$ is given by the functional

$$T[q] = \int_{t_1}^{t_2} L(q(t), \dot{q}(t), t)\, dt. \tag{2.1}$$

Here L plays the role of a Lagrangian. The key L2 claim is that the gradient-flow postulate applied to $T[q]$ reproduces the familiar Euler–Lagrange equations of classical mechanics.

2.2 L1 Dictionary for the Mechanical Example

At the dictionary level we make the identifications

- Container state $q(t) \leftrightarrow$ position of a point mass in one dimension.
- Coarse-grained velocity $\dot{q}(t) \leftrightarrow$ time derivative of q.
- Tension density $L(q, \dot{q}, t) \leftrightarrow$ Lagrangian $L = T_{\text{kin}} - V$, where T_{kin} is kinetic energy and V is potential energy.
- Tension functional $T[q] \leftrightarrow$ action $S[q] = \int L\, dt$.

This is purely L1: it states how familiar objects in mechanics can be read inside the kernel language, but it does not yet prove that the kernel dynamics reproduces mechanical trajectories.

2.3 L2: From Gradient Flow to Euler–Lagrange Equations

We now sketch how the gradient-flow postulate applied to $T[q]$ produces the Euler–Lagrange equations in the continuum limit.

Let $q(\tau, t)$ denote the configuration of the container at kernel update parameter τ and physical time t.[1] For each fixed τ we can evaluate the functional

$$T[q(\tau, \cdot)] = \int_{t_1}^{t_2} L(q(\tau, t), \partial_t q(\tau, t), t)\, dt. \tag{2.2}$$

The gradient-flow postulate suggests an evolution in configuration space of the form

$$\frac{\partial}{\partial \tau} q(\tau, t) = -k\, \frac{\delta T}{\delta q(\tau, t)}. \tag{2.3}$$

[1] The distinction between update parameter τ and physical time t is subtle but does not matter for the present schematic argument.

The functional derivative of T with respect to q is

$$\frac{\delta T}{\delta q(t)} = \frac{\partial L}{\partial q} - \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}}\right), \tag{2.4}$$

so that the gradient-flow equation becomes

$$\frac{\partial}{\partial \tau} q(\tau, t) = -k\left[\frac{\partial L}{\partial q} - \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}}\right)\right]. \tag{2.5}$$

In the limit $\tau \to \infty$, the flow converges to configurations for which $\partial q/\partial \tau = 0$, leading to

$$\frac{\partial L}{\partial q} - \frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}}\right) = 0. \tag{2.6}$$

This is precisely the Euler–Lagrange equation of classical mechanics.

Thus, at the L2 level, the kernel assumption of gradient flow on a tension functional induces an effective least-action principle in the continuous limit, thereby reproducing ordinary Lagrangian mechanics for appropriate choices of L.

2.4 Example: Free Particle and Harmonic Oscillator

For a point mass m in one dimension with potential $V(q)$, we choose

$$L(q, \dot{q}) = \frac{1}{2} m \dot{q}^2 - V(q). \tag{2.7}$$

The Euler–Lagrange equation yields

$$m\ddot{q} + V'(q) = 0, \tag{2.8}$$

or $m\ddot{q} = -V'(q)$, which is Newton's second law with force $F(q) = -V'(q)$.

For the harmonic oscillator with $V(q) = \frac{1}{2} k q^2$, we obtain

$$m\ddot{q} + kq = 0, \tag{2.9}$$

demonstrating that standard classical trajectories can be viewed as fixed points of tension-gradient descent in the kernel description.

3 Fields and Electromagnetic Analogy from Kernel Flux

3.1 Containers, Flux, and Conservation

In the kernel picture, a field is represented not by a continuous value at each point in space, but by patterns of weights on edges of the graph. Consider a collection of containers arranged in a regular spatial structure. For each container we can define an effective field value by averaging or coarse-graining edge weights that cross a local surface.

Let C be a container with boundary ∂C. Define a discrete flux through ∂C as

$$\Phi_C = \sum_{(u,v)\in \partial C} \omega(u, v), \tag{3.1}$$

where the sum is taken over directed edges crossing the boundary in the outward direction and $\omega(u, v)$ is the associated weight.

A conservation law on the kernel states that, for each container and for each update step,

$$\Delta Q_C + \Delta \Phi_C = 0, \tag{3.2}$$

where ΔQ_C is the net change of some quantity stored inside C and $\Delta \Phi_C$ is the net flux through the boundary during the same step.

3.2 L1 Dictionary to Continuum Fields

At the L1 level we map:

- Discrete flux $\Phi_C \leftrightarrow$ surface integral of a vector field over ∂C.
- Stored quantity $Q_C \leftrightarrow$ volume integral of a charge or mass density over C.
- Discrete conservation law $\Delta Q_C + \Delta \Phi_C = 0 \leftrightarrow$ local conservation equations in continuum field theory.

In a regular lattice with spacing a, we can define a coarse-grained vector field $\mathbf{E}(\mathbf{x})$ such that the flux through the boundary of a cell is approximated by

$$\Phi_C \approx \int_{\partial C} \mathbf{E} \cdot d\mathbf{S}. \tag{3.3}$$

Similarly, the stored quantity Q_C is approximated by

$$Q_C \approx \int_C \rho(\mathbf{x})\, d^3x, \tag{3.4}$$

where ρ is a density field.

3.3 L2: Gauss-Type Law from Kernel Conservation

Assume that, in the continuum limit, the discrete conservation law becomes

$$\frac{d}{dt} \int_C \rho(\mathbf{x}, t)\, d^3x + \int_{\partial C} \mathbf{E}(\mathbf{x}, t) \cdot d\mathbf{S} = 0 \tag{3.5}$$

for all sufficiently regular regions C. Using the divergence theorem,

$$\int_{\partial C} \mathbf{E} \cdot d\mathbf{S} = \int_C \nabla \cdot \mathbf{E}\, d^3x, \tag{3.6}$$

we obtain

$$\int_C \left(\frac{\partial \rho}{\partial t} + \nabla \cdot \mathbf{E} \right) d^3x = 0. \tag{3.7}$$

If this holds for all regions C, the integrand must vanish:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \mathbf{E} = 0. \tag{3.8}$$

This is a continuity equation with current density $\mathbf{J} = -\mathbf{E}$.

In electrostatics the charge density is time independent; then the continuity equation reduces to

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}, \tag{3.9}$$

which is Gauss's law for the electric field.

Thus a discrete conservation rule on kernel containers, together with a suitable continuum limit, structurally reproduces Gauss-type field equations at the L2 level.

3.4 Discussion

The point is not that HOK derives electromagnetism from first principles, but that a single kernel language can naturally host the same kinds of conservation and flux structures that underlie classical field theory. This will later be combined with quantum considerations and with entanglement across boundaries when discussing gravity.

4 Thermodynamics and Information in the Kernel

We now turn to thermodynamic and information-theoretic behaviour. The goal of this section is threefold:

1. to provide an L1 dictionary between kernel configurations and thermodynamic macrostates;
2. to show how standard entropy functionals arise at the L2 level;
3. to outline how Landauer's principle appears in the kernel language, opening an L3 route toward the Boltzmann constant k_B.

4.1 L1 Dictionary: Microstates, Macrostates, and Temperature

Consider a container C inside the kernel graph $\mathcal{G}$ with node set N_C and edge set E_C.

Definition 4.1 (Microstate of a container)**.** *A microstate of C is a restriction of the global configuration $\Psi \in \Omega$ to the degrees of freedom associated with N_C and E_C. The set of all accessible microstates consistent with the constraints on C is denoted by Γ_C.*

Definition 4.2 (Macrostate of a container)**.** *A macrostate of C is an equivalence class of microstates in Γ_C that share a given set of coarse-grained properties, such as total energy, particle number, or other conserved quantities. We denote such a macrostate by M.*

At the L1 level we identify:

- Microstate $\gamma \in \Gamma_C \leftrightarrow$ microscopic configuration in statistical mechanics.
- Macrostate $M \leftrightarrow$ thermodynamic state specified by macroscopic variables.
- Probability distribution $p(\gamma)$ over $\Gamma_C \leftrightarrow$ ensemble in equilibrium or non-equilibrium statistical mechanics.

An effective temperature T can be introduced in the usual way by relating changes in internal energy to changes in entropy, once the entropy functional has been defined.

4.2 L2: Entropy Functionals

Let $p(\gamma)$ be a probability distribution over microstates $\gamma \in \Gamma_C$ of container C.

Definition 4.3 (Shannon information entropy)**.** *The Shannon entropy of p is*

$$H[p] = -\sum_{\gamma \in \Gamma_C} p(\gamma) \log_2 p(\gamma) \quad \textit{bits.} \tag{4.1}$$

Definition 4.4 (Thermodynamic entropy)**.** *The thermodynamic entropy associated with p is*

$$S[p] = k_B \ln W \tag{4.2}$$

for the microcanonical ensemble with W equiprobable microstates, and more generally

$$S[p] = -k_B \sum_{\gamma \in \Gamma_C} p(\gamma) \ln p(\gamma). \tag{4.3}$$

At the L2 level, nothing exotic is assumed: the kernel simply provides the underlying set of microstates Γ_C and a mechanism by which probabilities $p(\gamma)$ arise from interaction with other containers and environments.

4.3 Landauer Principle in the Kernel

Landauer's principle states that erasing one bit of information in a system at temperature T requires dissipating at least

$$\Delta Q_{\min} = k_B T \ln 2 \tag{4.4}$$

of heat into the environment. Equivalently, the entropy of the environment must increase by at least

$$\Delta S_{\text{env}} \geq k_B \ln 2 \tag{4.5}$$

per bit erased.

In the kernel language we interpret a single logical bit as a robust distinction between two sets of container microstates. Let a container C encode a bit in two disjoint subsets Γ_0 and Γ_1 of Γ_C.

- A logically reversible operation permutes microstates within Γ_0 and Γ_1 without merging them.
- A logically irreversible erasure maps both Γ_0 and Γ_1 into (approximately) the same macrostate set Γ_{reset}.

At the kernel level, erasure corresponds to redirecting tension flows so that all microstates that previously encoded different bit values are driven into the same region of configuration space. This requires a reduction of entropy for container C, and therefore, by the second law, an entropy increase in the environment.

The standard Landauer bound is recovered when we assume that the environment is large, remains near equilibrium at temperature T, and that the erasure operation is implemented quasi-statically. In that case the minimal entropy exported to the environment per bit is $k_B \ln 2$.

4.4 Toward an L3 Mapping of k_B

The L3 program for k_B in the kernel framework can be sketched as follows:

1. Define a minimal robust kernel operation that implements a logical bit and its erasure for a container.
2. Determine the minimal tension change ε^* required for this erasure, under the kernel dynamics and under physically reasonable constraints (for example, no access to infinite resources).
3. Relate ε^* to an effective temperature T of the environment, and show that $\varepsilon^* \approx k_B T \ln 2$.

If such a program can be completed for a concrete class of kernel models, it would express the Boltzmann constant k_B in terms of more primitive kernel quantities such as typical tension scales and update rates.

5 Quantum Interference and Decoherence in the Kernel

5.1 Path Amplitudes and the Double-Slit Experiment

To connect the kernel language with quantum mechanics, we consider histories of a container that can follow different paths through the graph. A simple example is an analogue of the double-slit experiment.

Let a particle-like container start at a source S and be detected at a screen point x. There are two coarse-grained classes of kernel histories:

- histories that pass through region A (slit 1),
- histories that pass through region B (slit 2).

We assign a complex amplitude to each history

$$\mathcal{A}[h] = \exp\left(\frac{i}{\hbar_{\text{eff}}} S[h]\right), \tag{5.1}$$

where $S[h]$ is an effective action functional that depends on the tension along the history h, and $\hbar_{\text{eff}}$ is an effective constant with dimensions of action.

The total amplitude for detection at x is

$$\mathcal{A}(x) = \sum_{h \in \mathcal{H}(x)} \mathcal{A}[h], \tag{5.2}$$

where the sum runs over all relevant histories $\mathcal{H}(x)$ that connect S to x. The probability density for detection is then

$$P(x) \propto |\mathcal{A}(x)|^2. \tag{5.3}$$

When both regions A and B are open, the set of histories splits into two families, and the amplitude decomposes as

$$\mathcal{A}(x) = \mathcal{A}_A(x) + \mathcal{A}_B(x), \tag{5.4}$$

leading to the interference pattern

$$P(x) \propto |\mathcal{A}_A(x) + \mathcal{A}_B(x)|^2. \tag{5.5}$$

5.2 Decoherence as Entanglement with Pointer Containers

In realistic situations, the container carrying the particle interacts with additional containers that record which-path information. These pointer containers become entangled with the path degree of freedom.

At the kernel level, we regard the global state as a configuration over a product Hilbert space

$$\mathcal{H} = \mathcal{H}_{\text{path}} \otimes \mathcal{H}_{\text{pointer}} \otimes \mathcal{H}_{\text{env}}. \tag{5.6}$$

An initial state with no which-path information can be written as

$$|\Psi_{\text{init}}\rangle = (\alpha\,|A\rangle + \beta\,|B\rangle) \otimes |0\rangle_{\text{pointer}} \otimes |E_0\rangle_{\text{env}}\,. \tag{5.7}$$

Interaction between the path container and the pointer container induces the transformation

$$|A\rangle\,|0\rangle \to |A\rangle\,|A\rangle\,, \qquad |B\rangle\,|0\rangle \to |B\rangle\,|B\rangle\,, \tag{5.8}$$

so that the joint state becomes

$$|\Psi\rangle = \alpha\,|A\rangle\,|A\rangle\,|E_A\rangle + \beta\,|B\rangle\,|B\rangle\,|E_B\rangle\,, \tag{5.9}$$

where $|E_A\rangle$ and $|E_B\rangle$ are environment states correlated with the two branches.

The reduced density matrix for the path degree of freedom is obtained by tracing over the pointer and environment:

$$\rho_{\text{path}} = \text{Tr}_{\text{pointer, env}}\,|\Psi\rangle\,\langle\Psi|\,. \tag{5.10}$$

If the environment states are nearly orthogonal, $\langle E_A|E_B\rangle \approx 0$, the off-diagonal terms in ρ_{path} are strongly suppressed and interference disappears at the level of observable probabilities.

Thus decoherence appears as a structural consequence of entanglement between containers and their environments in the kernel description.

5.3 Toward an L3 Mapping of $\hbar$

The effective constant $\hbar_{\text{eff}}$ in the phase factor $\exp(iS[h]/\hbar_{\text{eff}})$ plays the same structural role as Planck's constant in standard quantum mechanics. An L3 program for $\hbar$ in the kernel framework would proceed along the following lines:

1. Identify minimal non-zero increments of effective action $\Delta S_{\min}$ associated with elementary kernel updates.
2. Require that interference patterns are governed by phase differences of the form $\exp(i\Delta S/\hbar_{\text{eff}})$ and that histories with $\Delta S \gg \hbar_{\text{eff}}$ effectively decohere.
3. Relate $\hbar_{\text{eff}}$ to $\Delta S_{\min}$ and to kernel parameters such as update rates and typical tension scales, and match the result to the observed Planck constant $\hbar$.

Completing such a program would express $\hbar$ in terms of deeper kernel quantities, in analogy with the proposed program for k_B.

6 Geometry, Horizons, and Emergent Gravity

6.1 Effective Geometry on the Kernel

In general relativity, gravity is encoded in a Lorentzian metric $g_{\mu\nu}$ on a differentiable manifold, with freely falling bodies following geodesics. In the kernel framework, the starting point is instead a dynamic graph $\mathcal{G}(\tau)$ with weighted edges.

We can define an effective distance between nodes by assigning costs to paths. For nodes u and v, let $d(u, v)$ be the minimal cost over all paths from u to v, where the cost is a functional of the edge weights. At large scales, subsets of N can be embedded into a continuous manifold with a metric $g_{\mu\nu}$ chosen so that geodesics approximate minimal-cost paths on the graph.

At the L1 level we make the correspondence:

- Node and edge structure $\leftrightarrow$ events and causal relations.
- Effective distance $d(u, v) \leftrightarrow$ spacetime interval.
- Curvature of $g_{\mu\nu} \leftrightarrow$ non-uniform patterns of tension and connectivity in the kernel.

6.2 Horizon-Like Boundaries

Horizons in gravity, such as black-hole event horizons or Rindler horizons for accelerated observers, are surfaces beyond which information cannot influence an observer in finite time.

Definition 6.1 (Horizon-like boundary)**.** *A horizon-like boundary in the kernel is a boundary B separating two regions of the graph such that:*

- *For a given class of observers confined to one side, any path from their region to the other must traverse edges in B.*
- *Effective signal propagation across B is limited by a speed bound and by constraints on edge weights, so that information from beyond B cannot influence the observer region within finite emergent time.*

Such boundaries behave like causal screens. They naturally support entropy proportional to their effective area, because they restrict access to degrees of freedom behind the boundary and therefore give rise to entanglement.

6.3 Entanglement Entropy and Area Law

Partition the kernel into two regions, A and its complement A^c, separated by a boundary B. At an effective Hilbert-space level, let the global state be a pure state on $\mathcal{H}_A \otimes \mathcal{H}_{A^c}$ with reduced state $\rho_A = \mathrm{Tr}_{A^c} |\Psi\rangle \langle\Psi|$. The entanglement entropy is

$$S_{\mathrm{ent}}(A) = -\mathrm{Tr}(\rho_A \log \rho_A). \tag{6.1}$$

Many quantum lattice systems exhibit an area law: for suitable states,

$$S_{\mathrm{ent}}(A) \approx \kappa\, k_B \frac{A(B)}{l_*^2}, \tag{6.2}$$

where $A(B)$ is the effective area of the boundary, l_* is a microscopic length scale, and κ is a dimensionless constant of order unity.

6.4 Black-Hole Entropy and the Form of G

In semiclassical gravity, a stationary black hole with horizon area A has entropy

$$S_{\mathrm{BH}} = \frac{k_B c^3}{4G\hbar} A. \tag{6.3}$$

Assume that:

1. A black-hole horizon corresponds to a horizon-like boundary B in the kernel with area $A(B) = A$.
2. The entanglement entropy across B satisfies the area law
$$S_{\mathrm{ent}}(A) \approx \kappa\, k_B \frac{A}{l_*^2}. \tag{6.4}$$
3. This entropy is identified with S_{BH}.

Equating the two expressions and cancelling k_B and A gives

$$\kappa \frac{1}{l_*^2} \approx \frac{c^3}{4G\hbar}. \tag{6.5}$$

Solving for G yields

$$G_{\mathrm{eff}} \approx \frac{c^3 l_*^2}{4\kappa\hbar}. \tag{6.6}$$

Comparing this with Postulate 1.2,

$$G_{\mathrm{eff}} \approx \eta \frac{c^3 l_*^2}{\hbar}, \tag{6.7}$$

we see that consistency requires

$$\eta \approx \frac{1}{4\kappa}. \tag{6.8}$$

Thus the dimensionless factor η appearing in the structural form of G is directly linked to the coefficient κ in the entanglement area law on the kernel.

6.5 Toward an L3 Program for G

An L3 program for G would:

1. Specify concrete classes of kernel graphs with microscopic scale l_* and well-defined dynamics.
2. Compute entanglement entropy across large boundaries and extract the area-law coefficient κ.
3. Use the relation $G_{\text{eff}} \approx c^3 l_*^2/(4\kappa\hbar)$ to determine G_{eff} and compare with the observed Newton constant.
4. Check consistency with other phenomena, such as non-gravitating entanglement entropy and container dynamics at intermediate scales.

Whether such a program can be carried out in practice is a nontrivial question. The point of this section is to show that the kernel framework provides a natural stage on which standard relations between entropy, area, and gravity can be expressed.

7 L3 Programs and Falsifiability

7.1 Summary of L1 and L2 Status

The HOK Physics Kernel uses three conceptual levels:

- L1: dictionary from kernel objects to standard mathematical and physical objects.
- L2: structural dynamics showing that, under stated assumptions, kernel evolution reproduces familiar equations.
- L3: attempts to derive or constrain numerical constants and to make testable predictions.

In this document we have:

- provided L1 mappings for classical mechanics, fields, thermodynamics, quantum interference, and gravity;
- shown at L2 that gradient flow on a tension functional yields Euler–Lagrange equations for effective coordinates;
- shown that discrete conservation of flux leads to Gauss-type field laws in the continuum limit;
- connected kernel microstates and probability distributions to standard entropy functionals and to Landauer's principle;
- sketched how entanglement across kernel boundaries can support an area law and reproduce the structural form of Newton's constant.

These are not proofs that HOK is the correct underlying description of nature, but they demonstrate that a single kernel language can host the structures of several major areas of physics.

7.2 Summary of L3 Programs

The main L3 targets are:

- k_B**:** express the minimal energy cost of erasing a bit, ε^*, in terms of kernel quantities and show that $\varepsilon^* \approx k_B T \ln 2$ for appropriate environments.
- $\hbar$**:** relate the effective action scale governing interference, $\hbar_{\text{eff}}$, to minimal increments of tension or action in the kernel and match it to Planck's constant.
- G**:** compute entanglement entropy across kernel boundaries, extract the area-law coefficient κ, and determine G_{eff} through $G_{\text{eff}} \approx c^3 l_*^2/(4\kappa\hbar)$.
- **Gauge and curvature structure:** derive effective gauge fields and spacetime curvature from holonomies and symmetry properties of the kernel graph.
- **Phenomenology:** identify small deviations from standard physics (for example, corrections to area laws or dispersion relations) that could serve as experimental tests.

7.3 Falsifiability Criteria

A useful framework must be able to fail. The HOK Physics Kernel can be falsified in several ways:

- **Incompatibility with well-tested structures.** If it can be shown that no kernel dynamics satisfying the HOK axioms can reproduce classical mechanics, standard conservation laws, or familiar thermodynamic behaviour, the framework would have to be abandoned or radically modified.
- **Failure of area laws.** If, for all reasonable kernel models, entanglement entropy generically scales with volume rather than area for horizon-like partitions, the proposed route to G via entanglement would be undermined.
- **Inability to match constants.** If no plausible choice of kernel microstructure can simultaneously match the observed values of k_B, $\hbar$, and G within experimental uncertainty, the framework would lose credibility as a foundational candidate.
- **Conflict with experiment.** If concrete kernel models predict deviations from standard physics that are ruled out by experiment, those models, and possibly the entire framework, would be falsified.
- **Internal inconsistency.** If the requirement of stable container dynamics, well-defined entropies, and causal structure leads to contradictions, the model would not be viable.

7.4 Outlook

At this v0.1 stage the HOK Physics Kernel should be viewed as a structured interface between a graph-based ontic model and existing physical theories. It offers:

- a unified vocabulary for discussing fields, containers, boundaries, vectors, and tension;
- structural demonstrations that this vocabulary can reproduce familiar equations in appropriate limits;
- a set of L3 research programs whose success or failure will determine whether the kernel deserves to be taken seriously as a foundational hypothesis.

Future work must move beyond structural analogies and tackle specific, computable kernel models. Only then can the framework progress from a Rosetta stone for existing theories to a quantitative proposal about what the universe is made of and why its constants take the values they do.