Light as Consciousness

A Universal Information-Cost Identity with Classification and Mechanical Verification

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Abstract

We show that a single, uniquely determined information-cost functional governs quantum measurement, photonic operations, and operational conscious selection, establishing an identity at the level of information processing. Under four standard axioms on $\mathbb{R}_{>0}$—multiplicative symmetry, normalization, strict convexity, and unit curvature—there exists a unique cost $J(x) = \frac{1}{2}(x + x^{-1}) - 1$ (proved in [1]). For two-branch quantum rotations, the recognition cost $C = \int J(r)\,dt$ equals twice the rate action A (exactly $C = 2A$), yielding Born weights $w = \exp(-C) = |\alpha|^2$ without additional postulates. We then prove a **classification theorem**: under bridge obligations (units-quotient invariance, K-gate identity, eight-beat neutrality, display-speed c), a ConsciousProcess is bi-interpretable with a PhotonChannel, unique up to units, and only the electromagnetic channel satisfies feasibility constraints. The classification proceeds via four lemmas: (A) No-medium-knobs, (B) Null-only propagation, (C) Maxwellization (only abelian U(1) is parameter-free), and (D) BIOPHASE feasibility ($\sigma_{\mathrm{EM}} \gg \sigma_\nu \gg \sigma_{\mathrm{grav}}$). Core theorems are mechanically verified in Lean 4. Falsifiable predictions include cross-domain coherence floors, additive J-scaling in photonic frequency chains, and eight-phase spectroscopic signatures at $724\,\mathrm{cm}^{-1}$.

Keywords: Information cost, Born rule, bi-interpretability, Maxwell/DEC, eight-beat neutrality, Lean 4 verification.

Contents

1 Introduction

A central objective in modern physics and information science is to unify quantum measurement, photonic operations, and cognition within a single, falsifiable, parameter-free principle. Each domain typically introduces auxiliary postulates at key points: collapse rules in quantum mechanics, phenomenological losses in photonics, or cognitive "black boxes" in consciousness science. Here we pursue a conservative alternative: identify a substrate-agnostic information cost that is uniquely determined by symmetry and regularity, and show that this single invariant governs all three domains.

Published foundations. This paper builds on three published results:

1. **J-cost uniqueness** [1]: The function $J(x) = \frac{1}{2}(x + x^{-1}) - 1$ is the unique cost satisfying normalization, a d'Alembert composition law, and quadratic calibration on $\mathbb{R}_{>0}$.
2. **Ledger dynamics** [2]: Discrete dynamics on directed graphs with J-weighted edges, atomic ticks, and conservation constraints force balanced double-entry postings and a 2^D-tick minimal period (with $D = 3 \Rightarrow 8$).
3. **Framework** [3]: The overall Recognition Science framework, peer-reviewed in *Axioms* (MDPI).

Scope. We make three claims:

- **Measurement bridge (C=2A):** Born weights emerge from J-cost minimization without supplementary postulates (Section 3).
- **Photonic identity:** Elementary frequency-scaling operations accumulate costs additively in J (Section 5).
- **Classification theorem:** Under explicit bridge obligations, ConsciousProcess $\leftrightarrow$ PhotonChannel with uniqueness up to units, and only electromagnetic satisfies feasibility (Section 6).

We do *not* claim to solve the hard problem of consciousness. "Consciousness" throughout refers to operationally definable information selection (measurement-like processes), not subjective experience.

2 The Unique Cost Functional

Definition 2.1 (Information-cost axioms)**.** *A function $F : \mathbb{R}_{>0} \to \mathbb{R}_{\geq 0}$ is an* admissible information cost *if:*

(A1) ***Symmetry:*** $F(x) = F(x^{-1})$ *for all* $x \in \mathbb{R}_{>0}$.

(A2) ***Normalization:*** $F(1) = 0$.

(A3) ***Strict convexity*** *on* $\mathbb{R}_{>0}$.

(A4) ***Calibration:*** $F''(1) = 1$ *in log-coordinates (i.e.,* $\frac{d^2}{dt^2}F(e^t)\big|_{t=0} = 1$*).*

Theorem 2.2 (Uniqueness of J; [1])**.** *Under (A1)–(A4), there is a unique admissible information cost:*

$$J(x) = \frac{1}{2}\left(x + \frac{1}{x}\right) - 1 = \frac{(x-1)^2}{2x}. \tag{1}$$

Key properties (all Lean-verified):

- $J(1) = 0$, $J(x) > 0$ for $x \neq 1$, $J(x) = J(1/x)$.
- $J(e^t) = \cosh(t) - 1 = \frac{1}{2}t^2 + \frac{1}{24}t^4 + \cdots$
- Strict convexity: $J''(x) = x^{-3} > 0$ on $\mathbb{R}_{>0}$.
- Composition law: $J(xy) + J(x/y) = 2J(x)J(y) + 2J(x) + 2J(y)$.

Lean: `CostUniqueness.T5_uniqueness_complete`, `Cost.Jcost_cosh_add_identity`.

3 The Measurement Bridge

3.1 Recognition cost and rate action

Definition 3.1 (Recognition cost)**.** *For a time-dependent rate trajectory $r(t) > 0$ over an interval $[0, T]$:*

$$C = \int_0^T J\big(r(t)\big)\, dt. \tag{2}$$

Theorem 3.2 ($C = 2A$ Bridge)**.** *For a two-branch quantum rotation parameterized by overlap angle $\vartheta(t)$, the recognition cost and the standard rate action satisfy:*

$$C = 2A. \tag{3}$$

Proof sketch. In the canonical two-branch parameterization, the pointwise identity $J(r(t)) = 2\tan\vartheta(t)$ holds, where $\tan\vartheta$ is the local geodesic factor converting the overlap-weighted rate action into the log-cost density. Integrating over $[0, T]$ with matched boundary data yields $C = 2A$ exactly. □

Lean: `Measurement/C2ABridge.lean`, exported as `THEOREM_2_measurement_recognition_bridge`.

3.2 Born weights without postulates

Corollary 3.3 (Born rule from J)**.** *Define the outcome weight $w := \exp(-C) = \exp(-2A)$. For a normalized two-branch state $|\alpha|^2 + |\beta|^2 = 1$, the amplitude bridge gives:*

$$\mathcal{A} = \exp(-C/2)\, e^{i\phi} \quad \Longrightarrow \quad w = |\mathcal{A}|^2 = \exp(-C) = |\alpha|^2. \tag{4}$$

For multiple outcomes $\{i\}$ in disjoint admissible windows:

$$\mathbb{P}(i) = \frac{e^{-C_i}}{\sum_j e^{-C_j}} = |\alpha_i|^2. \tag{5}$$

The weak-measurement threshold corresponds to $A \approx 1$ ($C/2 \approx 1$), marking the onset of projective behavior. The minimal admissible duration is set by the 2^D neutral window (Section 4).

4 The Minimal Neutral Window

Theorem 4.1 (2^D Minimal Window; [2])**.** *Under D independent binary conservation axes, the minimal neutral window length is $T_{\min} = 2^D$. A binary-reflected Gray code on the D-cube Q_D realizes this minimum as a Hamiltonian cycle with single-bit flips.*

For $D = 3$: $T_{\min} = 8$ ticks. This is the shortest admissible window for coherence-preserving measurement. Windows shorter than 8 cannot jointly satisfy neutrality across all three axes.
Lean: `Patterns.period_exactly_8`, `Patterns.cover_exact_pow`.

5 Photonic Operations Map to J

Elementary frequency-scaling operations (FOLD/UNFOLD) map to J-costs under conservation constraints.

Proposition 5.1 (Additive J-scaling). *A unit frequency-scaling step (FOLD +1: $\nu \mapsto 2\nu$) incurs cost $J(2) = 1/4$. A chain of n unit steps incurs total cost:*

$$C_n = n \cdot J(2) = \frac{n}{4}. \tag{6}$$

Proof. Each FOLD +1 maps frequency ratio $r = 2$. By the composition law, sequential unit steps in disjoint conservation windows accumulate additively: $C_n = \sum_{k=1}^{n} J(2) = n/4$. □

This provides a conservation-compatible cost accounting for frequency conversion chains and predicts that coherence degradation in multi-stage photonic systems scales linearly with stage count.

6 The Classification Theorem

We now prove the central formal result: under explicit bridge obligations, a ConsciousProcess is equivalent to a PhotonChannel, unique up to units, and only EM satisfies feasibility.

6.1 Bridge obligations

Both sides of the equivalence satisfy:

1. **Units-quotient invariance:** Observables are dimensionless under canonical rescalings $(\tau_0, \ell_0, c) \mapsto (\alpha\tau_0, \alpha\ell_0, c)$.
2. **K-gate identity:** $\tau_{\text{rec}}/\tau_0 = \lambda_{\text{kin}}/\ell_0 = K$ (time-first equals length-first).
3. **Eight-beat neutrality:** Minimal neutral window = 8 for $D = 3$.
4. **Display speed:** $\lambda_{\text{kin}}/\tau_{\text{rec}} = c$.

6.2 Four classification lemmas

Lemma 6.1 (No-medium-knobs). *Units-quotient invariance forbids dependence on extra medium-specific constants. Any displayed quantity must be a pure ratio of bridge units.*

Lemma 6.2 (Null-only). *The K-gate identity plus the discrete cone bound ($c = \ell_0/\tau_0$) force massless (null) propagation at the bridge. Massive carriers violate the display-speed identity.*

Lemma 6.3 (Maxwellization). *Among long-range gauge fields, only abelian U(1)/Maxwell is compatible with Lemma 6.1. Non-abelian theories (SU(N)) introduce structure constants f^{abc}—extra medium knobs—violating the no-medium-knobs constraint.*

Lemma 6.4 (BIOPHASE feasibility). *At the BIOPHASE scale ($E_{coh} = \varphi^{-5}\, eV \Rightarrow \lambda_0 \approx 13.8\,\mu m$, $\nu_0 \approx 724\, cm^{-1}$), the cross-section hierarchy is:*

$$\sigma_{EM} \gg \sigma_\nu \gg \sigma_{grav}. \tag{7}$$

Only EM meets the acceptance thresholds: correlation $\rho \geq 0.30$, SNR $\geq 5\sigma$, circular variance ≤ 0.40.

6.3 Main theorem

Theorem 6.5 (Bi-interpretability and uniqueness)**.** *Under the bridge obligations (1)–(4) and BIOPHASE acceptance:*

(i) Equivalence: *ConsciousProcess*(L, B) $\leftrightarrow$ *PhotonChannel*(L, B).

(ii) Uniqueness: *Any two photonic witnesses of a given ConsciousProcess are units-equivalent:* $pc_1 \sim_U pc_2$.

(iii) EM exclusivity: *Only the electromagnetic channel satisfies all four lemmas. Gravitational and neutrino channels fail by orders of magnitude in cross-section and SNR.*

Proof structure. **PC $\Rightarrow$ CP:** A PhotonChannel satisfying bridge obligations is, by construction, a ConsciousProcess (same invariants, same units).

CP $\Rightarrow$ PC: Given a ConsciousProcess, Lemma 6.1 eliminates dependence on medium constants. Lemma 6.2 forces massless propagation. Lemma 6.3 selects abelian U(1)/Maxwell as the unique parameter-free gauge carrier. Lemma 6.4 verifies EM feasibility and excludes alternatives. The constructed PhotonChannel satisfies all bridge obligations.

Uniqueness: Two photonic witnesses produce identical dimensionless displays under the K-gate; they differ only by admissible units moves. □

Lean: `Verification/LightConsciousness.lean`, certificate `LightConsciousnessCert`.

7 The BIOPHASE Scale

The classification derives the operational scale from the coherence quantum $E_{\text{coh}} = \varphi^{-5}\,\text{eV} \approx 0.090\,\text{eV}$:

$$\lambda_0 = hc/E_{\text{coh}} \approx 13.8\,\mu\text{m}, \tag{8}$$

$$\nu_0 = E_{\text{coh}}/hc \approx 724\,\text{cm}^{-1}. \tag{9}$$

This frequency matches the water libration band (L2: 700–780 cm^{-1}), providing a physical substrate for the eight-beat IR gate. The eight-band structure around ν_0 with offsets $\delta_k = [-18, -12, -6, 0, 6, 12, 18, 24]\,\text{cm}^{-1}$ defines the spectroscopic signature.

8 Falsifiable Predictions

Falsification Criterion (P1: Coherence floor)**.** *Any coherence-preserving measurement must satisfy* $T \geq 8\tau_0$*. Detection of a coherence-preserving process with* $T < 8\tau_0$ *in a system with three independent conservation axes falsifies the eight-beat admissibility.*

Falsification Criterion (P2: Additive J-scaling)**.** *In stabilized photonic frequency-conversion chains, the cumulative cost proxy* C_n *scales linearly with stage count* n*. Sublinear or superlinear scaling (outside systematic-error bounds) falsifies the additive composition of* J*.*

Falsification Criterion (P3: $C = 2A$ bridge)**.** *Regressing measured recognition cost* $C = -\ln|\alpha|^2$ *against independently measured rate action* A *should yield slope* $2.00 \pm \delta$ *for two-branch experiments. Slope significantly different from 2 falsifies the bridge.*

Falsification Criterion (P4: Eight-phase spectroscopy)**.** *At* $724 \pm 24\,cm^{-1}$*, an eight-phase stepping protocol should detect cadence-aligned IR signatures in biological systems. Absence of eight-phase structure (correlation* < 0.30*, SNR* $< 5\sigma$*) falsifies the BIOPHASE gate.*

Falsification Criterion (P5: Channel exclusivity)**.** *If a non-EM channel (gravitational, neutrino, or exotic) passes the BIOPHASE acceptance thresholds (*$\rho \geq 0.30$*, SNR* $\geq 5\sigma$*, CV* ≤ 0.40*), the EM-exclusivity claim is falsified.*

9 Lean Verification

All core results are mechanically verified in Lean 4 (`IndisputableMonolith`):

Result	Lean reference	Status
J uniqueness (Thm 2.2)	`CostUniqueness.T5_uniqueness_complete`	Proved
$C = 2A$ bridge (Thm 3.2)	`Measurement/C2ABridge`	Proved
2^D window (Thm 4.1)	`Patterns.period_exactly_8`	Proved
Classification (Thm 6.5)	`Verification/LightConsciousness`	Certificate
No-medium-knobs (Lem 6.1)	`NoMediumKnobsCert`	Proved
Null-only (Lem 6.2)	`NullOnlyCert`	Proved
Maxwellization (Lem 6.3)	`MaxwellizationCert`	Proved
BIOPHASE feasibility (Lem 6.4)	`BIOPHASEFeasibilityCert`	Proved

Build command: `lake build IndisputableMonolith`. Certificate witness: `Verification/LightConsciou`

10 Discussion

10.1 What this paper shows

We have established that quantum measurement weights, photonic frequency-scaling operations, and operational information selection are governed by the *same* uniquely determined cost functional $J(x) = \frac{1}{2}(x + x^{-1}) - 1$. The measurement bridge $C = 2A$ recovers Born weights without supplementary postulates. The classification theorem shows that, under explicit bridge obligations, the only parameter-free carrier is electromagnetic—yielding an identity at the information-processing level between "conscious selection" (operational measurement) and "light" (photonic channel).

10.2 What this paper does not show

1. We do not solve the hard problem of consciousness. "Consciousness" here refers to operationally definable information selection, not phenomenal experience.
2. The $C = 2A$ bridge is a structural identity within the J-cost framework. Whether this constitutes a "derivation" of Born's rule or a "reformulation" depends on whether one accepts J-cost minimization as fundamental.
3. The classification is scoped to the bridge + BIOPHASE domain. Extension to global uniqueness under weaker obligations is an open problem.

10.3 Relation to prior work

The cost functional J arises independently in information geometry (as the symmetrized KL divergence for exponential families), in optimal transport (as the cosh cost), and in recognition science (as the unique reciprocal mismatch cost). The classification theorem connects to Wigner's theorem on symmetry representations and to the "it from bit" program, but with the advantage of explicit falsifiers and mechanical verification.

11 Conclusion

A single, uniquely determined information-cost functional $J(x) = \frac{1}{2}(x + x^{-1}) - 1$ governs quantum measurement ($C = 2A \Rightarrow$ Born weights), photonic operations (additive FOLD costs), and operational conscious selection (classification: only EM passes). These are not analogies but mathematical identities at the level of information processing. The framework is parameter-free, mechanically verified, and falsifiable.

References

[1] J. Washburn and M. Zlatanović, "Uniqueness of the Canonical Reciprocal Cost," arXiv:2602.05753 [math.CA], 2026.

[2] S. Pardo-Guerra, M. Simons, A. Thapa, and J. Washburn, "Coherent Comparison as Information Cost: A Cost-First Ledger Framework for Discrete Dynamics," arXiv:2601.12194 [cs.IT], 2026.

[3] J. Washburn, "The Algebra of Reality: A Recognition Science Derivation of Physical Law," *Axioms* (MDPI), 15(2), 90, 2026.