# The Emergence of Proper Time from Energy and Resistance

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**Abstract**

This paper proposes a physically grounded and system–centric definition of time. Time is redefined as proper time – the measurable internal transformation of a system as energy overcomes resistance. This intrinsic duration arises from a conserved causal capacity partitioned between internal evolution and external motion. A system experiences time only to the extent that it undergoes internal change, while massless systems, lacking internal transformation, experience none. Time is thus interpreted as a localized, emergent, and relational property of causal structure rather than an external backdrop, consistent with relativistic invariance and thermodynamic irreversibility. In this system–centric formulation, durations and rates are defined from each system's own physical perspective, avoiding observer–centric language and emphasizing that causal suppression is an objective physical effect, not a matter of observational standpoint.

*Keywords:* time, proper time, causal structure, physical transformation, relational ontology, emergence of time



## 1. Introduction

The nature of time remains one of the most enduring problems in physics and philosophy [9]. While classical physics treats time as an absolute backdrop [1], relativity reframes it as a dimension interwoven with space and unifies both into a geometric framework [3, 2], and thermodynamics links time's arrow to entropy [4, 5], these perspectives all leave unresolved the question of *what time physically is*.

We define time operationally through energy and power: it exists only where energy is transformed through resistance. This yields a concrete physical and relational understanding of temporal experience.

## 2. Time as Internal Physical Transformation

We define time as the intrinsic duration of causal evolution within a system. More precisely:

**Definition.** *Time is proper time. It is the continuous physical change or evolution that any system undergoes, perceived only through comparison with a prior state and calibrated either by a co–moving reference clock or by the invariant speed of light c via* (3)*. This evolution represents a real, measurable process in which energy overcomes internal opposition within the system (cf. [8], where energy quantization establishes discrete thresholds for transformation).*

**Postulate 1 (Transformation).** *Every physical transformation is characterized by an energy $E$ and a calibrated opposition force $F_{cal}$, which together define a universal causal throughput, where $c$ is the invariant causal rate. Here, $F_{cal}$ is the generalized opposition to transformation (mechanical inertia, thermal capacity, electromagnetic impedance, etc.; see Table 1), calibrated via $c$ to ensure domain–independence:*

$$F_{cal} = \frac{P}{c}. \tag{1}$$

*The structural extent of the transformation is then*

$$\mathcal{T} = \frac{E}{F_{cal}} = \frac{E\,c}{P}, \tag{2}$$

*which has units of length. The corresponding proper time (duration) is*

$$\tau = \frac{\mathcal{T}}{c} = \frac{E}{P}. \tag{3}$$

*Meaning.* The structural measure $\mathcal{T}$ quantifies the transformation extent of a system by comparison with the causal horizon set by light: it is the distance light would travel during the intrinsic proper time required for the system's internal change. Time is thus a relational, causal measure of physical transformation, not an external backdrop.

*Connection to conventional mechanics.* In classical mechanics, the external/domain power is $P_{\text{ext}} = F_{\text{ext}}\,v$ with $F_{\text{ext}} = ma$, hence $F_{\text{ext}} = P_{\text{ext}}/v$. From $\mathcal{T} = E/F_{\text{ext}}$ one obtains a non–calibrated, domain form

$$\mathcal{T} = \frac{E\,v}{P_{\text{ext}}}, \tag{4}$$

which depends on the external speed $v$. To obtain a domain–agnostic measure, replace the domain velocity by the invariant causal rate via $F_{\text{cal}} = P/c$, giving $\mathcal{T} = Ec/P$ in (2). *Role separation:* do not combine $F_{\text{cal}}$ with $F_{\text{ext}} = P_{\text{ext}}/v$ to infer $v = c$; $F_{\text{cal}}$ (timing channel) and $F_{\text{ext}}$ (external dynamics) play different roles.

*Proper time and motion–induced suppression.* When a subsystem moves at speed $v$ (in the lab frame where $P$ is evaluated), the universal causal budget partitions in quadrature

$$c^2 = v^2 + v_{\text{int}}^2, \qquad v_{\text{int}} = \sqrt{c^2 - v^2},$$

so the internal throughput is suppressed:

$$P_{\text{int}}(v) = F_{\text{cal}}\, v_{\text{int}} = \frac{P}{c}\sqrt{c^2 - v^2} = P\sqrt{1 - \frac{v^2}{c^2}}.$$

The realized internal structural advance and proper time over the same interval are

$$\mathcal{T}(v) = \frac{E}{F_{\text{cal}}}\sqrt{1 - \frac{v^2}{c^2}} \;=\; \frac{E\,c}{P}\sqrt{1 - \frac{v^2}{c^2}}, \tag{5}$$

$$\tau(v) = \frac{\mathcal{T}(v)}{c} \;=\; \frac{E}{P}\sqrt{1 - \frac{v^2}{c^2}}. \tag{6}$$

At rest ($v = 0$), we have $P = P_0$, so $\tau(0) = E/P = E/P_0$ and $\mathcal{T}(0) = Ec/P = Ec/P_0$. The factor $\sqrt{1 - v^2/c^2}$ is the familiar Lorentz suppression, here interpreted structurally: motion amplifies the effective opposition in the internal channel, reducing the internal share of the causal budget.

*Two common use–cases (same formulas, different givens):*

- **Interval view (tick suppression).** If $E$ is the energy delivered in the lab frame during a fixed lab–frame interval with power $P$, then

$$\frac{\tau(v)}{\tau(0)} = \sqrt{1 - \frac{v^2}{c^2}}, \qquad \tau(0) = \frac{E}{P}.$$

  *(Optionally omit "lab–frame" qualifiers if context is clear.)*

- **Task–completion view (fixed internal budget $E_0$, fixed rest power $P_0$).** The system must complete a fixed internal transformation requiring energy $E_0$ at its rest–frame power $P_0$. Since the internal power available in the lab frame is suppressed to $P_{\text{int}}(v) = P\sqrt{1 - v^2/c^2} = P_0$, we have $P = \gamma P_0$ and thus the lab–frame time dilates as

$$t_{\text{lab}}(v) \;=\; \frac{E_0}{P_{\text{int}}(v)} \;=\; \frac{E_0}{P_0}\,\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \;=\; \gamma\,\frac{E_0}{P_0},$$

while the proper time to complete the task remains

$$\Delta\tau \;=\; \frac{E_0}{P_0} \quad \text{(independent of } v\text{)}.$$

*Units check.* $[F_{\mathrm{cal}}] = [P/c] = (\mathrm{J/s})/(\mathrm{m/s}) = \mathrm{J/m} = \mathrm{N}$. Hence $\mathcal{T} = E/F_{\mathrm{cal}}$ has units of meters, and $\tau = \mathcal{T}/c = E/P$ has seconds, as required.

*Variable power.* If the lab power varies in time, the integral forms apply:

$$\Delta\tau = \int \frac{\mathrm{d}E}{P(t)}, \qquad \mathcal{T} = \int \frac{c\,\mathrm{d}E}{P(t)}.$$

### *2.1. Domain–Specific Forms of Power and Calibrated Opposition*

Table 1: Domain laws and calibrated opposition used for timing and extent

| **Domain** | **Power Law** | **Calibrated Opposition** $F_{\mathrm{cal}}$ | **Interpretation / Notes** |
|---|---|---|---|
| Mechanics | $P_{\mathrm{ext}} = F_{\mathrm{ext}}\,v$ | $F_{\mathrm{cal}} = P/c$ | Keep $P_{\mathrm{ext}} = F_{\mathrm{ext}}v$ for external application; use $F_{\mathrm{cal}}$ only for $\mathcal{T}$ (cf. 1). |
| Thermodynamics | $P_{\mathrm{th}} = C\,\dot{T}$ | $F_{\mathrm{cal}} = P/c$ | Heat capacity $C$ encodes opposition to temperature change (include losses/phase terms as needed). Timing/extent via $\mathcal{T} = E/F_{\mathrm{cal}} = Ec/P$. |
| Electromagnetism | $P_{\mathrm{em}} = V I$ | $F_{\mathrm{cal}} = P/c$ | Circuit power mapped to a common opposition unit (J/m). Domain impedance $Z = V/I$ remains domain–specific; $F_{\mathrm{cal}}$ is universal for timing. |
| Gravitation | $P_{\mathrm{grav}} = \dot{m}\,\Phi$ | $F_{\mathrm{cal}} = P/c$ | Potential–energy flux ($\Phi$ in J/kg). Calibrated opposition defines transformation rate uniformly with other domains. |
| Quantum | $P_{\mathrm{q}} = \hbar\omega\,\Gamma$ | $F_{\mathrm{cal}} = P/c$ | Transition power from excitation/decay ($\Gamma = 1/\tau$). Structural extent $\mathcal{T} = Ec/P$; duration $\tau = E/P$. |

*Note.* In every domain, $F_{\mathrm{cal}} = P/c$ maps native power to a unified opposition with units $\mathrm{J/m} = \mathrm{N}$, yielding the domain–agnostic relations $\mathcal{T} = E/F_{\mathrm{cal}} = Ec/P$ (meters) and $\tau = \mathcal{T}/c = E/P$ (seconds).

*Optional: Rest–power relation*

Let $P_0$ be the power measured in the system's rest frame. Using $P_{\text{int}}(v) = F_{\text{cal}} v_{\text{int}}$ with $v_{\text{int}} = \sqrt{c^2 - v^2}$ and $F_{\text{cal}} = P/c$,

$$P_{\text{int}}(v) = P\sqrt{1 - \frac{v^2}{c^2}}.$$

If internal physics is unchanged by motion, equate the internal throughput to the rest power: $P_0 = P_{\text{int}}(v)$. Then

$$P \;=\; \gamma\, P_0, \qquad \gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}. \tag{7}$$

This is consistent with (5)–(6) and the two use–cases above.

## 3. Ontological Implications

*1. Time is Localized.* Each system evolves according to its own internal causal dynamics. There is no global or universal clock – only local durations defined by the ratio of energy to resistance within each transformation. Synchronization between systems is not absolute but emerges through causal interaction and mutual energy exchange.

*2. Massless Systems are Timeless.* For photons and other massless entities, the internal causal rate satisfies $v_{\text{int}} = 0$, yielding $\tau = 0$. Such systems mediate causal relations among massive systems but do not themselves transform internally. They participate in the transmission of causality without experiencing duration.

*3. Coordinate Time as Convention.* The coordinate label $\mathcal{T} = c\,t$ is not an independent form of time but a representational convention – an external bookkeeping device used to order transformations. It refers to when a state occurred relative to others within a single causal reality. The parameter $t$ thus quantifies correlation between events, not the physical flow of an underlying medium.

*4. Absence of an Arrow of Time.* Within this framework, there is no fundamental arrow of time. Time does not flow or advance; it is the measured outcome of transformation itself. Systems evolve from one state to another as energy overcomes resistance, and this sequence defines what we perceive as temporal progression. The universe does not move through time – transformations simply occur, and their cumulative record constitutes what we describe as history.

## 4. Relational Time

The experience of time is relational, arising through mutual transformation among interacting systems. While each system evolves at its own proper time $\tau$, these systems influence one another, embedding individual timelines into a larger causal structure. This perspective aligns with relational and process-based approaches to physics [6, 10, 7, 5].

## 5. Causal budget allocation

### *5.1. Postulate and empirical basis*

All systems transform continuously. We posit a fixed causal capacity $c$ allocated between external motion and internal evolution:

$$c^2 = v_{\text{ext}}^2 + v_{\text{int}}^2, \tag{8}$$

where $v_{\text{ext}}$ is the spatial speed and $v_{\text{int}} = \frac{d\mathcal{T}}{dt}$ is the internal transformation rate – how much intrinsic evolution $\mathcal{T}$ unfolds per unit external time $t$ (both in m/s). This expression emphasizes a duality of causal motion: external displacement through space versus internal transformation in time.

At rest, the system has no spatial motion ($v_{\text{ext}} = 0$), so all causal activity manifests as internal evolution: $v_{\text{int}} = c$. In the lightlike limit ($v_{\text{ext}} \to c$), internal transformation halts: $v_{\text{int}} \to 0$. This reflects the trade-off between motion through space and motion through intrinsic time under a fixed causal bound.

*Empirical foundation.* We do not introduce a new constant: $c$ is the empirically invariant two-way signal speed fixed in SI. The framework uses $c$ as the universal calibration already embedded in operational identities linking energy, power, and force – radiation pressure $F = P/c$, mass–energy $E = \Delta m\, c^2$, and momentum/energy flux $S/c^2$. Thus (Equation 8) is a conservation statement enforcing the observed bound on causal propagation, not a new spacetime postulate. If $c$ were not finite and invariant, these identities would fail; their ubiquitous success justifies treating $c$ as the maximal causal rate in this formulation.

#### *5.1.1. Derivation from first principles*

The causal budget law can be derived from three fundamental principles:

1. **Conservation:** Total causal capacity $c^2$ is invariant and conserved
2. **Independence:** External motion and internal evolution are independent transformation modes
3. **Boundary conditions:** $v_{\text{ext}} = 0 \Rightarrow v_{\text{int}} = c$ and $v_{\text{ext}} = c \Rightarrow v_{\text{int}} = 0$

These conditions define a continuous relationship between $v_{\text{ext}}$ and $v_{\text{int}}$ passing through $(0, c)$ and $(c, 0)$ while conserving a fixed total. The simplest geometric object connecting perpendicular components to an invariant total is a right triangle with hypotenuse $c$, giving the Pythagorean form (Figure 1).

This derivation uses only conservation principles and boundary conditions – not spacetime geometry. The quadratic form ensures invariant total causal activity $c^2$ under exchange between independent transformation modes. A linear sum would fail to preserve invariance and depend on direction of $v_{\text{ext}}$.

This Pythagorean form emerges from conservation plus independence, not from spatial geometry.[1]

*Relation to the spacetime geometry formulation.* The causal-budget law (8), yields the same mathematical structure as the constancy of the four-velocity norm $u_\mu u^\mu = c^2$ in special relativity. This formal equivalence ensures empirical consistency, yet conceals a fundamental conceptual shift.

In the geometric formulation, the invariance of $c$ is a *postulate* embedded in Minkowski spacetime. In the present framework, it is *derived* from conservation of causal capacity – an operational constraint on transformation rates – without presuming any geometric structure. Spacetime geometry thus appears as an emergent representation of this underlying causal balance [11], not as a primitive ingredient of reality.

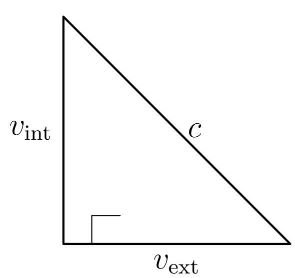


Figure 1: Causal budget triangle: the total causal rate $c$ is partitioned into external and internal components, $v_{\text{ext}}$ and $v_{\text{int}}$, satisfying $c^2 = v_{\text{ext}}^2 + v_{\text{int}}^2$.

### 5.2. Massless and massive limits

For photons $v_{\text{ext}} = c$ so $v_{\text{int}} = 0$: all capacity goes to propagation and $\Delta\tau = 0$. Massive systems require $v_{\text{int}} > 0$, hence $v_{\text{ext}} < c$. The speed bound arises from causal-capacity conservation, not geometric postulates.

[1] Mathematically this is the same reason Pythagorean relations appear in power triangles ($S^2 = P^2 + Q^2$) and in variance addition ($\sigma_{\text{tot}}^2 = \sigma_1^2 + \sigma_2^2$): a conserved total partitioned between independent components.

### 5.3. Lorentz factor derivation

During the lab–frame interval $\Delta t_{\mathrm{lab}}$, the internal structural advance is $\mathcal{T}_{\mathrm{int}} = v_{\mathrm{int}}\,\Delta t_{\mathrm{lab}}$; for a co–moving (proper) clock the same advance is $c\,\Delta\tau$. Using the causal budget $c^2 = v^2 + v_{\mathrm{int}}^2$ (see Eq. 8) and equating advances,

$$c\,\Delta\tau \;=\; v_{\mathrm{int}}\,\Delta t_{\mathrm{lab}} \;=\; \sqrt{c^2 - v^2}\,\Delta t_{\mathrm{lab}},$$

so

$$\Delta\tau \;=\; \Delta t_{\mathrm{lab}}\sqrt{1-\frac{v^2}{c^2}} \qquad\Longleftrightarrow\qquad \Delta t_{\mathrm{lab}} \;=\; \gamma\,\Delta\tau,\;\; \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}.$$

## 6. Operational Foundations

*From geometry to measurement.* While general relativity quantifies gravity through spacetime curvature, the present framework operationalizes gravitational effects through *measurable transformation rates.* The fundamental objects are not metric components $g_{\mu\nu}$ but causal relations between physical processes:

- **Time** – proper time measured via the transformation ratio $\tau = E/P$ (Eq. 3).
- **Space** – calibrated by causal signal propagation at the invariant rate $c$, with structural extent $\mathcal{T} = E/F_{\mathrm{cal}} = Ec/P$ (Eq. 2).
- **Gravity** – manifests as a universal suppression of transformation rates governed by the causal-budget law $c^2 = v_{\mathrm{ext}}^2 + v_{\mathrm{int}}^2$ (Eq. 8); in the weak field this corresponds to $f_t^2 = 1 + 2\Phi/c^2$ and $\psi^4 = 1 - 2\Phi/c^2$.

*Conceptual advantage.* This approach avoids committing to an underlying spacetime manifold and instead builds physics from operational principles: what clocks measure, how energies transform, and what causal constraints bound these processes.

## 7. Conclusion

Time exists only through physical transformation. Proper time is the sole form of time that possesses ontological reality; all other notions derive from it as relational constructs. *This leads to a stark ontological conclusion: only systems undergoing physical transformation have time. Proper time is time – nothing else is.*

## Appendix A. Parallel Evolution and Coexistence

Each system evolves according to its own proper time, driven by internal transformation. These evolutions occur concurrently but not synchronously: distinct systems undergo change at different rates, depending on their energy and resistance. Time, in this sense, is local and relational – there is no universal clock, only the coordination of causal processes.

An everyday analogy is the relation between two people living in different cities – say, Boston and London – each going about their daily lives. While they coexist within the same world, the pace and sequence of their activities – waking, working, resting – unfold according to their own internal schedules, not some globally synchronized script.

Similarly, physical systems participate in a shared causal fabric, yet evolve along distinct proper timelines determined by their internal transformations. This coexistence without synchrony illustrates the relational nature of time: reality is not governed by a universal clock, but is a dynamic network of processes, each advancing at its own intrinsic rate. In this view, time is not an external backdrop, but the emergent structure of interwoven change.

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