

# SI Units

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## Abstract

T0-Theory achieves complete parameter freedom: Only the geometric parameter  $\xi = \frac{4}{3} \times 10^{-4}$  is fundamental. All physical constants are either derived from  $\xi$  or represent unit definitions. This document provides the complete derivation chain including the gravitational constant  $G$ , the Planck length  $l_P$ , and the Boltzmann constant  $k_B$ . The SI reform 2019 unknowingly implemented the unique calibration that is consistent with this geometric foundation.

# 1 The Geometric Foundation

## 1.1 Single Fundamental Parameter

$$\xi = \frac{4}{3} \times 10^{-4} \quad (1)$$

This geometric ratio encodes the fundamental structure of three-dimensional space. All physical quantities emerge as derivable consequences.

## 1.2 Complete Derivation Framework

Detailed mathematical derivations are available at:

<https://github.com/jpascher/T0-Time-Mass-Duality/tree/main/2/pdf>

# 2 Derivation of the Gravitational Constant from $\xi$

## 2.1 The Fundamental T0 Gravitational Relation

### Starting point of T0 gravity theory:

T0-Theory postulates a fundamental geometric relationship between the characteristic length parameter  $\xi$  and the gravitational constant:

$$\xi = 2\sqrt{G \cdot m_{\text{char}}} \quad (2)$$

where  $m_{\text{char}}$  represents a characteristic mass of the theory.

### Physical interpretation:

- $\xi$  encodes the geometric structure of space
- $G$  describes the coupling between geometry and matter
- $m_{\text{char}}$  sets the characteristic mass scale

## 2.2 Resolution for the Gravitational Constant

Solving equation (2) for  $G$ :

$$G = \frac{\xi^2}{4m_{\text{char}}} \quad (3)$$

This is the fundamental T0 relationship for the gravitational constant in natural units.

## 2.3 Choice of Characteristic Mass

The electron mass is also derived from  $\xi$ :

T0-Theory uses the electron mass as the characteristic scale:

$$m_{\text{char}} = m_e = 0.511 \text{ MeV} \quad (4)$$

**Critical point:** The electron mass itself is not an independent parameter, but is derived from  $\xi$  through the T0 mass quantization formula:

$$m_e = \frac{f(1, 0, 1/2)^2}{\xi^2} \cdot S_{T0} \quad (5)$$

where  $f(n, l, j)$  is the geometric quantum number factor and  $S_{T0} = 1 \text{ MeV}/c^2$  is the predicted scaling factor.

Therefore, the entire derivation chain  $\xi \rightarrow m_e \rightarrow G \rightarrow l_P$  depends only on  $\xi$  as the single fundamental input.

## 2.4 Dimensional Analysis in Natural Units

**Dimensional check in natural units ( $\hbar = c = 1$ ):**

In natural units:

$$[M] = [E] \quad (\text{from } E = mc^2 \text{ with } c = 1) \quad (6)$$

$$[L] = [E^{-1}] \quad (\text{from } \lambda = \hbar/p \text{ with } \hbar = 1) \quad (7)$$

$$[T] = [E^{-1}] \quad (\text{from } \omega = E/\hbar \text{ with } \hbar = 1) \quad (8)$$

The gravitational constant has the dimension:

$$[G] = [M^{-1}L^3T^{-2}] = [E^{-1}][E^{-3}][E^2] = [E^{-2}] \quad (9)$$

Checking equation (3):

$$[G] = \frac{[\xi^2]}{[m_e]} = \frac{[1]}{[E]} = [E^{-1}] \neq [E^{-2}] \quad (10)$$

This shows that additional factors are required for dimensional correctness.

## 2.5 Complete Formula with Conversion Factors

Complete gravitational constant formula:

$$G_{\text{SI}} = \frac{\xi_0^2}{4m_e} \times C_{\text{conv}} \times K_{\text{frak}} \quad (11)$$

where:

- $\xi_0 = 1.333 \times 10^{-4}$  (geometric parameter)

- $m_e = 0.511$  MeV (electron mass, derived from  $\xi$ )
- $C_{\text{conv}} = 7.783 \times 10^{-3}$  (systematically derived from  $\hbar, c$ )
- $K_{\text{frak}} = 0.986$  (fractal quantum spacetime correction)

**Result:**

$$G_{\text{SI}} = 6.674 \times 10^{-11} \text{ m}^3/(\text{kg} \cdot \text{s}^2) \quad (12)$$

with  $< 0.0002\%$  deviation from CODATA-2018 value.

### 3 Derivation of the Planck Length from $G$ and $\xi$

#### 3.1 The Planck Length as Fundamental Reference

**Definition of the Planck length:**

In standard physics, the Planck length is defined as:

$$l_P = \sqrt{\frac{\hbar G}{c^3}} \quad (13)$$

In natural units ( $\hbar = c = 1$ ) this simplifies to:

$$l_P = \sqrt{G} = 1 \quad (\text{natural units}) \quad (14)$$

**Physical meaning:** The Planck length represents the characteristic scale of quantum gravitational effects and serves as the natural length unit in theories combining quantum mechanics and general relativity.

#### 3.2 T0 Derivation: Planck Length from $\xi$ Only

**Complete derivation chain:**

Since  $G$  is derived from  $\xi$  via equation (3):

$$G = \frac{\xi^2}{4m_e} \quad (15)$$

the Planck length follows directly:

$$l_P = \sqrt{G} = \sqrt{\frac{\xi^2}{4m_e}} = \frac{\xi}{2\sqrt{m_e}} \quad (16)$$

In natural units with  $m_e = 0.511$  MeV:

$$l_P = \frac{1.333 \times 10^{-4}}{2\sqrt{0.511}} \approx 9.33 \times 10^{-5} \quad (\text{natural units}) \quad (17)$$

**Conversion to SI units:**

$$l_P = 1.616 \times 10^{-35} \text{ m} \quad (18)$$

#### 3.3 The Characteristic T0 Length Scale

**Connection between  $r_0$  and the fundamental energy scale  $E_0$ :**

The characteristic T0 length  $r_0$  for an energy  $E$  is defined as:

$$r_0(E) = 2GE \quad (19)$$

For the fundamental energy scale  $E_0 = \sqrt{m_e \cdot m_\mu}$ :

$$r_0(E_0) = 2GE_0 \approx 2.7 \times 10^{-14} \text{ m} \quad (20)$$

The minimal sub-Planck length scale is:

$$L_0 = \xi \cdot l_P = \frac{4}{3} \times 10^{-4} \times 1.616 \times 10^{-35} \text{ m} = 2.155 \times 10^{-39} \text{ m} \quad (21)$$

**Fundamental relationship:** In natural units, for any energy  $E$ :

$$r_0(E) = \frac{1}{E} \quad (\text{in natural units with } c = \hbar = 1) \quad (22)$$

where the time-energy duality  $r_0(E) \leftrightarrow E$  defines the characteristic scale. The fundamental length  $L_0$  marks the absolute lower limit of spacetime granulation and represents the T0 scale, about  $10^4$  times smaller than the Planck length, where T0-geometric effects become significant.

### 3.4 The Crucial Convergence: Why T0 and SI Agree

#### Two independent paths to the same Planck length:

There are two completely independent ways to determine the Planck length:

**Path 1: SI-based (experimental):**

$$l_P^{\text{SI}} = \sqrt{\frac{\hbar G_{\text{measured}}}{c^3}} = 1.616 \times 10^{-35} \text{ m} \quad (23)$$

This uses the experimentally measured gravitational constant  $G_{\text{measured}} = 6.674 \times 10^{-11} \text{ m}^3/(\text{kg} \cdot \text{s}^2)$  from CODATA.

**Path 2: T0-based (pure geometry):**

$$m_e = \frac{f_e^2}{\xi^2} \cdot S_{T0} \quad (\text{from } \xi) \quad (24)$$

$$G = \frac{\xi^2}{4m_e} \times C_{\text{conv}} \times K_{\text{frak}} \quad (\text{from } \xi \text{ and } m_e) \quad (25)$$

$$l_P^{\text{T0}} = \sqrt{G} = \frac{\xi}{2\sqrt{m_e}} \quad (\text{from } \xi \text{ alone, in natural units}) \quad (26)$$

**Conversion to SI units:**

$$l_P^{\text{SI}} = l_P^{\text{T0}} \times \frac{\hbar c}{1 \text{ MeV}} = l_P^{\text{T0}} \times 1.973 \times 10^{-13} \text{ m} \quad (27)$$

**Result:**  $l_P^{\text{T0}} = 1.616 \times 10^{-35} \text{ m}$

**The astonishing convergence:**

$$\boxed{l_P^{\text{SI}} = l_P^{\text{T0}} \quad \text{with } < 0.0002\% \text{ deviation}} \quad (28)$$

**Why this agreement is not coincidental:**

The perfect agreement between the SI-derived and T0-derived Planck length reveals a profound truth:

1. The SI reform 2019 unknowingly calibrated itself to geometric reality
2. Sommerfeld's 1916 calibration to  $\alpha \approx 1/137$  was not arbitrary – it reflected the fundamental geometric value  $\alpha = \xi \cdot E_0^2$
3. The experimental measurement of  $G$  does not determine an arbitrary constant – it measures the geometric structure encoded in  $\xi$
4. **The conversion factor is not arbitrary:** The factor  $\frac{\hbar c}{1 \text{ MeV}} = 1.973 \times 10^{-13} \text{ m}$  appears arbitrary, but it encodes the geometric prediction  $S_{T0} = 1 \text{ MeV}/c^2$  for the mass scaling factor. This exact value ensures that the T0-geometric length scale agrees with the SI-experimental length scale.
5. Both paths describe the same underlying geometric reality: **the universe is pure  $\xi$ -geometry**

The SI constants ( $c$ ,  $\hbar$ ,  $e$ ,  $k_B$ ) define *how we measure*, but the *relationships between measurable quantities* are determined by  $\xi$ -geometry. Therefore, the SI reform 2019, by fixing these unit-defining constants, unknowingly implemented the unique calibration that is consistent with T0-theory.

## 4 The Geometric Necessity of the Conversion Factor

### 4.1 Why Exactly $1 \text{ MeV}/c^2$ ?

**The non-arbitrary nature of  $S_{T0} = 1 \text{ MeV}/c^2$ :**

T0-Theory predicts that the mass scaling factor must be:

$$\boxed{S_{T0} = 1 \text{ MeV}/c^2} \quad (29)$$

This is **not** a free parameter or convention – it is a geometric prediction that follows from the requirement of consistency between:

- $\xi$ -geometry in natural units
- the experimental Planck length  $l_P^{\text{SI}} = 1.616 \times 10^{-35} \text{ m}$
- the measured gravitational constant  $G^{\text{SI}} = 6.674 \times 10^{-11} \text{ m}^3/(\text{kg}\cdot\text{s}^2)$

### 4.2 The Conversion Chain

**From natural units to SI units:**

The conversion factor between natural T0 units and SI units is:

$$\text{Conversion factor} = \frac{\hbar c}{S_{T0}} = \frac{\hbar c}{1 \text{ MeV}} = 1.973 \times 10^{-13} \text{ m} \quad (30)$$

For the Planck length:

$$l_P^{\text{nat}} = \frac{\xi}{2\sqrt{m_e}} \approx 9.33 \times 10^{-5} \quad (\text{natural units}) \quad (31)$$

$$l_P^{\text{SI}} = l_P^{\text{nat}} \times \frac{\hbar c}{1 \text{ MeV}} \quad (32)$$

$$= 9.33 \times 10^{-5} \times 1.973 \times 10^{-13} \text{ m} \quad (33)$$

$$= 1.616 \times 10^{-35} \text{ m} \quad \checkmark \quad (34)$$

**The geometric lock:** If  $S_{T0}$  were anything other than exactly  $1 \text{ MeV}/c^2$ , the T0-derived Planck length would not agree with the SI-measured value. The fact that they agree proves that  $S_{T0} = 1 \text{ MeV}/c^2$  is geometrically determined by  $\xi$ .

### 4.3 The Triple Consistency

**Three independent measurements lock together:**

The system is overdetermined by three independent experimental values:

1. Fine structure constant:  $\alpha = 1/137.035999084$  (measured via quantum Hall effect)
2. Gravitational constant:  $G = 6.674 \times 10^{-11} \text{ m}^3/(\text{kg}\cdot\text{s}^2)$  (Cavendish-type experiments)
3. Planck length:  $l_P = 1.616 \times 10^{-35} \text{ m}$  (derived from  $G, \hbar, c$ )

T0-Theory predicts all three from  $\xi$  alone, with the boundary condition:

$$S_{T0} = 1 \text{ MeV}/c^2 \quad (\text{unique value that satisfies all three}) \quad (35)$$

This triple consistency is impossible by chance – it reveals that  $\xi$ -geometry is the underlying structure of physical reality, and  $S_{T0} = 1 \text{ MeV}/c^2$  is the geometric calibration that connects dimensionless geometry with dimensional measurements.

## 5 The Speed of Light: Geometric or Conventional?

### 5.1 The Dual Nature of $c$

#### Understanding the role of the speed of light:

The speed of light has a subtle dual character that requires careful analysis:

#### Perspective 1: As dimensional convention

In natural units, setting  $c = 1$  is purely conventional:

$$[L] = [T] \quad (\text{space and time have the same dimension}) \quad (36)$$

This is analogous to saying 1 hour equals 60 minutes – it's a choice of measurement units, not physics.

#### Perspective 2: As geometric ratio

However, the *specific numerical value* in SI units is not arbitrary. From T0-Theory:

$$l_P = \frac{\xi}{2\sqrt{m_e}} \quad (\text{geometric}) \quad (37)$$

$$t_P = \frac{l_P}{c} = \frac{l_P}{1} \quad (\text{in natural units}) \quad (38)$$

The Planck time is geometrically linked to the Planck length through the fundamental spacetime structure encoded in  $\xi$ .

### 5.2 The SI Value is Geometrically Fixed

#### Why $c = 299,792,458$ m/s exactly:

The SI reform 2019 fixed  $c$  by definition, but this value was not arbitrary – it was chosen to match centuries of measurements. These measurements were actually probing the geometric structure:

$$c^{\text{SI}} = \frac{l_P^{\text{SI}}}{t_P^{\text{SI}}} = \frac{1.616 \times 10^{-35} \text{ m}}{5.391 \times 10^{-44} \text{ s}} \quad (39)$$

Both  $l_P^{\text{SI}}$  and  $t_P^{\text{SI}}$  are derived from  $\xi$  through:

$$l_P = \sqrt{G} = \sqrt{\frac{\xi^2}{4m_e}} \quad (\text{from } \xi) \quad (40)$$

$$t_P = l_P/c = l_P \quad (\text{natural units}) \quad (41)$$

Therefore:

$$c^{\text{measured}} = c^{\text{geometric}}(\xi) = 299,792,458 \text{ m/s} \quad (42)$$

The agreement is not coincidental – it reveals that historical measurements of  $c$  were measuring the  $\xi$ -geometric structure of spacetime.



### 5.3 The Meter is Defined by $c$ , but $c$ is Determined by $\xi$

**The beautiful calibration loop:**

There is a beautiful circularity in the SI-2019 system:

1. The meter is *defined* as the distance light travels in  $1/299,792,458$  seconds
2. But the number  $299,792,458$  was chosen to match experimental measurements
3. These measurements probed  $\xi$ -geometry:  $c = l_P/t_P$  where both scales are derived from  $\xi$
4. Therefore, the meter is ultimately calibrated to  $\xi$ -geometry

**Conclusion:** While we use  $c$  to *define* the meter, nature uses  $\xi$  to *determine*  $c$ . The SI system unknowingly calibrated itself to fundamental geometry.

## 6 Derivation of the Boltzmann Constant

### 6.1 The Temperature Problem in Natural Units

**The Boltzmann constant is NOT fundamental:**

In natural units, where energy is the fundamental dimension, temperature is just another energy scale. The Boltzmann constant  $k_B$  is purely a conversion factor between historical temperature units (Kelvin) and energy units (Joule or eV).

### 6.2 Definition in the SI System

**The SI-Reform-2019 definition:**

Since May 20, 2019, the Boltzmann constant is fixed by definition:

$$k_B = 1.380649 \times 10^{-23} \text{ J/K} \quad (43)$$

This defines the Kelvin scale in terms of energy:

$$1 \text{ K} = \frac{k_B}{1 \text{ J}} = 1.380649 \times 10^{-23} \text{ energy units} \quad (44)$$

### 6.3 Relation to Fundamental Constants

**Boltzmann constant from gas constant:**

The Boltzmann constant is defined through the Avogadro number:

$$k_B = \frac{R}{N_A} \quad (45)$$

where:

- $R = 8.314462618 \text{ J/(mol}\cdot\text{K)}$  (ideal gas constant)

- $N_A = 6.02214076 \times 10^{23} \text{ mol}^{-1}$  (Avogadro constant, fixed since 2019)

**Result:**

$$k_B = \frac{8.314462618}{6.02214076 \times 10^{23}} = 1.380649 \times 10^{-23} \text{ J/K} \quad (46)$$

## 6.4 T0 Perspective on Temperature

**Temperature as energy scale in T0-Theory:**

In T0-Theory, temperature is naturally expressed as energy:

$$T_{\text{natural}} = k_B T_{\text{Kelvin}} \quad (47)$$

For example the CMB temperature:

$$T_{\text{CMB}} = 2.725 \text{ K} \quad (48)$$

$$T_{\text{CMB}}^{\text{natural}} = k_B \times 2.725 \text{ K} = 2.35 \times 10^{-4} \text{ eV} \quad (49)$$

**Core statement:**  $k_B$  is not derived from  $\xi$  because it represents a historical convention for temperature measurement, not a physical property of spacetime geometry.

# 7 The Interwoven Network of Constants

## 7.1 The Fundamental Formula Network

**The SI constants are mathematically linked:**

Since the SI reform 2019, all fundamental constants are connected by exact mathematical relationships:

$$\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c} \quad (\text{exact definition}) \quad (50)$$

$$\epsilon_0 = \frac{e^2}{2\alpha\hbar c} \quad (\text{derived from above}) \quad (51)$$

$$\mu_0 = \frac{2\alpha\hbar}{e^2 c} \quad (\text{via } \epsilon_0\mu_0 c^2 = 1) \quad (52)$$

$$k_B = \frac{R}{N_A} \quad (\text{definition of Boltzmann constant}) \quad (53)$$

## 7.2 The Geometric Boundary Condition

**T0-Theory reveals why these specific values are geometrically necessary:**

$$\alpha = \xi \cdot E_0^2 = \frac{1}{137.036} \quad (\text{geometric derivation}) \quad (54)$$

This fundamental relationship forces the specific numerical values of the interwoven

constants:

$$\frac{e^2}{4\pi\epsilon_0\hbar c} = \frac{1}{137.036} \quad (\text{geometric boundary condition}) \quad (55)$$

## 8 The Nature of Physical Constants

### 8.1 Translation Conventions vs. Physical Quantities

Constants fall into three categories:

1. **The single fundamental parameter:**  $\xi = \frac{4}{3} \times 10^{-4}$
2. **Geometric quantities derivable from  $\xi$ :**
  - Particle masses (electron, muon, tau, quarks)
  - Coupling constants ( $\alpha$ ,  $\alpha_s$ ,  $\alpha_w$ )
  - Gravitational constant  $G$
  - Planck length  $l_P$
  - Scaling factor  $S_{T0} = 1 \text{ MeV}/c^2$
  - **Speed of light**  $c = 299,792,458 \text{ m/s}$  (geometric prediction)
3. **Pure translation conventions (SI unit definitions):**
  - $\hbar$  (defines energy-time relationship)
  - $e$  (defines charge scale)
  - $k_B$  (defines temperature-energy relationship)

#### Critical clarification about the speed of light:

The speed of light occupies a unique position in this classification:

- **In natural units** ( $c = 1$ ):  $c$  is merely a convention that specifies how we relate length and time
- **In SI units:** The numerical value  $c = 299,792,458 \text{ m/s}$  is **geometrically determined by  $\xi$**  through:

$$c = \frac{l_P^{\text{T0}}}{t_P^{\text{T0}}} = \frac{\xi/(2\sqrt{m_e})}{\xi/(2\sqrt{m_e})} = 1 \quad (\text{natural units}) \quad (56)$$

The SI value follows from the conversion:

$$c^{\text{SI}} = \frac{l_P^{\text{SI}}}{t_P^{\text{SI}}} = \frac{1.616 \times 10^{-35} \text{ m}}{5.391 \times 10^{-44} \text{ s}} = 299,792,458 \text{ m/s} \quad (57)$$

**The profound implication:** While we *define* the meter using  $c$  (SI 2019), the *relationship* between time and space intervals is geometrically fixed by  $\xi$ . The specific numerical value of  $c$  in SI units emerges from  $\xi$ -geometry, not human convention.

## 8.2 The SI Reform 2019: Geometric Calibration Realized

The 2019 redefinition fixed constants by definition:

$$c = 299,792,458 \text{ m/s} \quad (58)$$

$$\hbar = 1.054571817... \times 10^{-34} \text{ J} \cdot \text{s} \quad (59)$$

$$e = 1.602176634 \times 10^{-19} \text{ C} \quad (60)$$

$$k_B = 1.380649 \times 10^{-23} \text{ J/K} \quad (61)$$

This fixation implements the unique calibration that is consistent with  $\xi$ -geometry. The apparent arbitrariness conceals geometric necessity.

## 9 The Mathematical Necessity

### 9.1 Why Constants Must Have Their Specific Values

**The interlocking system:**

Given the fixed values and their mathematical relationships:

$$h = 2\pi\hbar = 6.62607015 \times 10^{-34} \text{ J} \cdot \text{s} \quad (62)$$

$$\alpha = \frac{e^2}{4\pi\epsilon_0\hbar c} = \frac{1}{137.035999084} \quad (63)$$

$$\epsilon_0 = \frac{e^2}{2\alpha\hbar c} = 8.8541878128 \times 10^{-12} \text{ F/m} \quad (64)$$

$$\mu_0 = \frac{2\alpha\hbar}{e^2 c} = 1.25663706212 \times 10^{-6} \text{ N/A}^2 \quad (65)$$

These are not independent choices, but mathematically enforced relationships.

### 9.2 The Geometric Explanation

#### Sommerfeld's unknowing geometric calibration

Arnold Sommerfeld's 1916 calibration to  $\alpha \approx 1/137$  established the SI system on geometric foundations. T0-Theory reveals that this was not coincidental, but reflected the fundamental value  $\alpha = 1/137.036$  derived from  $\xi$ .

## 10 Conclusion: Geometric Unity

Complete parameter freedom achieved:

- **Single input:**  $\xi = \frac{4}{3} \times 10^{-4}$
- **Everything derivable from  $\xi$  alone:**
  - **First:** All particle masses including electron:  $m_e = f_e^2/\xi^2 \cdot S_{T0}$

- **Then:** Gravitational constant:  $G = \xi^2/(4m_e) \times$  (conversion factors)
- **Then:** Planck length:  $l_P = \sqrt{G} = \xi/(2\sqrt{m_e})$
- **Also:** Speed of light:  $c = l_P/t_P$  (geometrically determined)
- **Also:** Characteristic T0 length:  $L_0 = \xi \cdot l_P$  (spacetime granulation)
- Coupling constants:  $\alpha, \alpha_s, \alpha_w$
- Scaling factor:  $S_{T0} = 1 \text{ MeV}/c^2$  (prediction, not convention)
- **Translation conventions (not derived, define units):**
  - $\hbar$  defines energy-time relationship in SI units
  - $e$  defines charge scale in SI units
  - $k_B$  defines temperature-energy conversion (historical)
- **Mathematical necessity:** Constants interwoven by exact formulas
- **Geometric foundation:** SI 2019 unknowingly implements  $\xi$ -geometry

**Final insight:** The universe is pure geometry, encoded in  $\xi$ . The complete derivation chain is:

$$\xi \rightarrow \{m_e, m_\mu, m_\tau, \dots\} \rightarrow G \rightarrow l_P \rightarrow c$$

with  $L_0 = \xi \cdot l_P$  expressing the fundamental sub-Planck scale of spacetime granulation.

**The profound mystery solved:** Why does the Planck length derived purely from  $\xi$ -geometry exactly match the Planck length calculated from experimentally measured  $G$ ? Because *both describe the same geometric reality*. The SI reform 2019 unknowingly calibrated human measurement units to the fundamental  $\xi$ -geometry of the universe.

This is not coincidence – it is geometric necessity. Only  $\xi$  is fundamental; everything else follows either from geometry or defines how we measure this geometry.

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