Chapter 4: The Coherent Bases and Their Boundaries

At the end of Chapter 2, we found ourselves surrounded by 288 constants, each a measured signature pressed into the fabric of physical law. These constants govern how particles interact, how forces propagate, and how time evolves. Together, they form the silent numerical architecture of atomic structure.

But where do these constants come from? Why is the speed of light what it is, and not double or half? Why does the electron have its particular mass? Why does the fine-structure constant possess its precise dimensionless value? These are questions that haunt anyone who has become aware of these built-in features of the world. Because while our best theories require these values in order to work, they offer no explanation of where they originate.

We measure them. That means we can report them only to the precision of our measurements. We use them in our equations. But we possess no structural account of their origins.

Some constants describe coupling strengths, others describe masses, momenta, or energies. Some have dimensions, others are dimensionless. Some appear in classical mechanics, others only in the quantum realm. What unites them is that they are all empirical—known only from measurement.

At its best, physics is a discipline of explanation: it seeks to reduce the arbitrary to the necessary. It looks for unity beneath complexity. And so, the constants of Nature stand as both triumph and limitation: they let us model the world with astonishing accuracy, but they also reveal the limits of our understanding.

If a theory of everything is to exist, then it must explain the constants of Nature. It must show why they take the values they do, and not others. And it must do so from principles more basic than the constants themselves. It must show how they arise.

The constants of Nature cannot remain brute facts inside any final account of reality. They must become consequences—expressions of something deeper. Something structural. Something geometric. Something that persists.

When one examines the constants of Nature, one by one, and comparing them to the rest of the set, the first thing that becomes apparent is that they form a conversation about the five bases of atomic logic and their boundaries. In other words, the constants of Nature repeatedly encode the five coherent bases of atomic logic—the second, meter, coulomb, kelvin, and kilogram—and their boundaries—t_p, l_p, q_p, T_p, m_p.

To see at a glance what I mean, the Planck constant—h—divided by the hertz-joule relationship—Hz ⁝ J—is equal to one second, exactly. (Since our highest precision measurements approach 14 significant digits of accuracy, we will call a 14-digit match *exact*—meaning as matched as can be checked against.) Notation note: In this book, the symbol ⁝ is used solely as shorthand for the word *relationship* in CODATA constant names. For example, Hz ⁝ J is the symbol for the *hertz-joule relationship*.

Here are several examples of simple combinations of constants of Nature that precisely encode one of the bases of atomic logic.[38]

exact matches (14 digit precision)

Planck constant ÷_hertz-joule relationship	$\frac{h}{\mathrm{Hz} \vdots \mathrm{J}} = 1.0000000000000$ second
conventional value of coulomb-90 ÷ conventional value of ampere-90	$\frac{\mathrm{C}_{90}}{\mathrm{A}_{90}} = 1.0000000000000$ second
conventional value of henry-90 ÷ conventional value of ohm-90	$\frac{\mathrm{H}_{90}}{\Omega_{90}} = 1.0000000000000$ second
conventional value of farad-90 × conventional value of ohm-90	$\mathrm{F}_{90} \times \Omega_{90} = 1.0000000000000$ second
√ of (convent. value of farad-90 × conventional value of henry-90)	$\sqrt{\mathrm{F}_{90} \times \mathrm{H}_{90}} = 0.9999999999999$ second
second radiation constant ÷ inverse meter-kelvin relationship	$\frac{c_2}{\frac{1}{\mathrm{m}} \vdots \mathrm{K}} = 1.0000000000000$ meter
speed of light ÷ inverse meter-hertz relationship	$\frac{c}{\frac{1}{\mathrm{m}} \vdots \mathrm{Hz}} = 1.0000000000000$ meter
hartree-electron volt relationship ÷ (electron charge × atomic unit of electric potential)	$\frac{E_h \vdots \mathrm{eV}}{e \times \mathrm{A}_{\mathrm{e\,pot}}} = 1.0000000000000$ coulomb
2π × Bohr magneton in eV/T ÷ quantum of circulation	$\frac{2\pi \times \mu_B / e}{q_c} = 1.0000000000000$ coulomb
kelvin-joule relationship ÷ Boltzmann constant	$\frac{\mathrm{K} \vdots \mathrm{J}}{k_B} = 1.0000000000000$ kelvin
kelvin-inverse meter relationship × second radiation constant	$\mathrm{K} \vdots \frac{1}{\mathrm{m}} \times c_2 = 0.9999999999999$ kelvin

hartree-kelvin relationship × kelvin-hartree relationship	$E_h ⋮ \mathrm{K} \times \mathrm{K} ⋮ E_h = 0.9999999999999$ kelvin
atomic mass unit-kelvin relationship × kelvin-atomic mass unit relationship	$\mathrm{A_{mass}} ⋮ \mathrm{K} \times \mathrm{K} ⋮ \mathrm{A_{mass}} = 0.9999999999999$ kelvin
kelvin-electron volt relationship ÷ Boltzmann constant in eV/K	$\frac{\mathrm{K} ⋮ \mathrm{eV}}{\dddot{k}_B} = 0.9999999999999$ kelvin
kilogram-hartree relationship × hartree-kilogram relationship	$\mathrm{kg} ⋮ E_h \times E_h ⋮ \mathrm{kg} = 0.9999999999999$ kilogram
atomic mass constant × kilogram-atomic mass constant relationship	$\mathrm{A_{mass}} \times \mathrm{kg} ⋮ \mathrm{A_{mass}} = 0.9999999999999$ kilogram

This is the first sign of structure worth investigating. The constants combine to recover the coherent bases of atomic logic. Nature is built from these atomic bases—structured into a coherent geometric language by them. The rest of this book will seek to elucidate what that language is.

The next thing we notice when examining the combinatorial relationships of the constants of Nature, is that there are also combinations of constants that encode the atomic bases to roughly seven-digit precision.

half-precision matches (~7 digits)

1 ÷ (speed of light × hertz-inverse meter relationship)	$\frac{1}{c \times \mathrm{Hz} ⋮ \frac{1}{\mathrm{m}}} = 0.9999999929954$ second
electron volt-hertz relationship ÷ (electron volt-inverse meter relationship × inverse meter-hertz relationship)	$\frac{\mathrm{eV} ⋮ \mathrm{Hz}}{\mathrm{eV} ⋮ \frac{1}{\mathrm{m}} \times \frac{1}{\mathrm{m}} ⋮ \mathrm{Hz}} = 0.9999999967253$ meter
(conven. value of coulomb-90 × conven. value of watt-90) ÷ (conven. value of ampere-90 × conven. value of volt-90)	$\frac{\mathrm{C_{90}} \times \mathrm{W_{90}}}{\mathrm{A_{90}} \times \mathrm{V_{90}}} = 1.0000000888706$ coulomb
(conven. value of henry-90 × conven. value of watt-90) ÷ (conven. value of ohm-90 × conven. value of volt-90)	$\frac{\mathrm{H_{90}} \times \mathrm{W_{90}}}{\Omega_{90} \times \mathrm{V_{90}}} = 1.0000000888706$ coulomb
2nd radiation constant × kilogram-hertz relationship ÷ speed of light	$\frac{c_2 \times \mathrm{kg} ⋮ \mathrm{Hz}}{c} = 0.9999999992472$ kelvin
hartree-kelvin relationship × kelvin-kilogram relationship ÷ fine-structure constant squared × electron mass	$\frac{E_h ⋮ \mathrm{K} \times \mathrm{K} ⋮ \mathrm{kg}}{\alpha^2 \times m_e} = 0.9999999978806$ kelvin

kelvin-joule relationship × hartree-kelvin relationship ÷ (fine-structure constant squared × speed of light squared × electron mass) $\frac{\text{K} : \text{J} \times E_h : \text{K}}{\alpha^2 \times c^2 \times m_e} = 0.9999999964655$ kelvin

kilogram-joule relationship ÷ speed of light squared $\frac{\text{kg} : \text{J}}{c^2} = 0.9999999985986$ kilogram

The constants of Nature encode the SI base units—because these are the coherent atomic bases.[39] Some combine to characterize those bases to all fourteen digits, others to roughly seven. This is our first hint of a 2-part structure in the connective logic of atoms.

> "Newton's theory already had the precision of something like one part in ten to the seven… And then Einstein comes along and produces a theory which is now known to have a precision something like one part in ten to the power fourteen."
> —Roger Penrose[40]

To find the pattern in a complex set of data, it is often useful to reduce the complexity of what you are looking at. In a data set with many different dimensions, one way of reducing complexity is to look for all the ways we can combine different constants of Nature—multiply or divide them—to yield an output with only a *single* dimension. When we do this, we may find that we have isolated either one coherent base of atomic logic—second, meter, coulomb, kelvin, kilogram—or one of the mysterious boundaries to those bases: a Planck constant: t_p, l_p, q_p, T_p, or m_p.

Here are some combinations of constants of Nature that encode the boundaries of atomic logic to roughly seven digits of precision.

$$t_p = \sqrt{\frac{\hbar\, G}{c^5}} = 5.391248(61) \times 10^{-44} \text{ second}$$

$$l_p = \sqrt{\frac{\hbar\, G}{c^3}} = 1.616255(18) \times 10^{-35} \text{ meter}$$

$$q_p = \sqrt{4\pi\, \varepsilon_0\, \hbar\, c} = 1.87554600606(15) \times 10^{-18} \text{ coulomb}$$

$$q_p = \sqrt{\frac{4\pi\,\hbar}{Z_0}} = 1.87554603783(80) \times 10^{-18}\ \text{coulomb}$$

$$T_p = \sqrt{\frac{\hbar\,c^5}{G\,{k_B}^2}} = 1.416784(16) \times 10^{32}\ \text{kelvin}$$

$$m_p = \sqrt{\frac{\hbar\,c}{G}} = 2.176434(24) \times 10^{-8}\ \text{kilogram}$$

Here, again, even when talking about the boundaries of atomic logic—instead of the atomic bases—we find a combinatorial structure in the constants of Nature: one that appears 2-part, with a clean division between full-precision and half-precision characterizations.

$t_p = 5.391247(60) \times 10^{-44}$ s	Planck time
$l_p = 1.616255(18) \times 10^{-35}$ m	Planck length
$q_p = 1.8755459 \times 10^{-18}$ C	Planck charge
$T_p = 1.416784(16) \times 10^{32}$ K	Planck temperature
$m_p = 2.176434(24) \times 10^{-8}$ kg	Planck mass

These Planck constants point toward a hidden bounded architecture. They are the natural boundaries in the constructive logic of atoms. They define the smallest possible amount of time in that logical system, the shortest possible length, the strongest possible charge, the hottest possible temperature, and the largest possible mass that can coherently engage with those minimums.

Together, the constants of Nature form a conversation about the five coherent bases of atomic logic—second, meter, coulomb, kelvin, kilogram—maintained by the five Planck boundaries. These bases and limits are woven into the logic of physical law. This is why physicists refer to Planck units as a "system of natural units."[41]

The trouble with trying to construct the constants of Nature from Planck boundaries is that we only know them to about seven significant digits. This precision limit isn't due to inadequate instrumentation—it is built into the way the constants interrelate with one another. When we report a Planck constant value, we are really reporting the range of values that different combinations of constants of Nature yield.

What if that ambiguity is a clue?

The Planck boundaries are derived from the constants of Nature. There are several ways to combine different sets of constants to reduce to a single dimensional expression, resolving the inbuilt boundary of that dimension. But when we do this, we get the same number for about the first seven digits, and then we get divergence. When we report the value of the Planck constants, we are reporting the range of values this search yields.

To construct a world from Planck boundaries, we must define them geometrically. Not as products of empirical constants, but as structural features of a deeper space—a space with an exact partition logic, symmetries, and boundaries of its own. A space in which persistence is possible, and from which the constants could naturally emerge as expressions of how that persistence is structured.

That became the quest. To define the Planck boundaries geometrically. To understand the constants of Nature not from experiment alone, but from the very logic of the arena they shape together. To discover what reality must be like for these constants to arise from structure rather than remain unexplained inputs.