

The Yamagishi Planck Length Unpacking Theory ($l_p = c^{-3/2}$)

— 4th Edition: Counting the Degrees of Freedom, and Where the Half-Integer Exponents Come From — [Paper

39]

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— *From thinking to syncing.* —

ABSTRACT

Substituting the Yamagishi gravitational patch $G = 4\pi$ and quantum patch $\hbar = \frac{1}{4\pi}$ into the Planck length $l_p = \sqrt{\hbar G/c^3}$ cancels $\hbar G = 1$ and gives $l_p = c^{-3/2}$. The substitution is correct. The 3rd edition puts this expression through the "counting of degrees of freedom" of Paper 38 (3rd edition). First, the count. Any three of $\hbar, G, c, m$ are dimensionally independent (their determinant is non-zero), and since there are only three base dimensions M, L, T , at most three quantities may be assigned values. Imposing a value on a fourth is not a convention but a claim about nature. This paper spends two of the three, on G and $\hbar$; $l_p = c^{-3/2}$ is therefore an expression with one degree of freedom still unspent. Spending the last on $c = 1$ gives $l_p = 1$ — the Planck length becomes the unit of length, which is precisely the definition of Planck units. Second, where the exponent $3/2$ comes from. Writing $l_p = \hbar^a G^b c^d$ and matching dimensions determines $(a, b, d) = (\frac{1}{2}, \frac{1}{2}, -\frac{3}{2})$ uniquely. The exponent is thus the solution of a 3×3 system of linear equations and contains no dynamics whatsoever. Third, why Planck units are full of square roots. The dimension-exponent matrix of $(\hbar, G, c)$ has invariant factors $(1, 1, 2)$, that is, largest invariant factor 2. What fixes the denominators of the entries of the inverse is not the determinant but the largest invariant factor (Paper 149). Here $|\det|$ is also 2, but that is only an upper bound on what the denominator divides ($\text{diag}(2, 2)$ has $|\det| = 4$ and yields half-integers only). The cokernel here is $\mathbb{Z}/2$ and hence cyclic, so the two happen to agree. That the exponents of the Planck length, time, mass and energy are all half-integers is a consequence of that largest invariant factor being 2. By contrast the basis (G, m, c) of Paper 38 has invariant factors $(1, 1, 1)$ and yields integer exponents (the natural length is Gm/c^2 and the natural energy is mc^2). Change the basis and the kind of exponent changes. Fourth, the 4π inside $\hbar = \frac{1}{4\pi}$ is not an independent occurrence. It is the reciprocal of the chosen G , selected so that $\hbar G = 1$, and carries no information beyond the choice of G . It has nothing to do with the solid-angle 4π (Root 1 of Paper 35, 3rd edition). Fifth, the Planck length is not a minimum length. No established theory says so. It is the place where the dimensionless ratio E/E_p crosses one — a module boundary in the sense of Paper 113, and the location of the difficulty Paper 35 (3rd edition) identified in $[G] = M^{-2}$. The second edition's rejection of the identification with Kepler's third law was correct; the 3rd edition gives that distinction a name in the vocabulary of Paper 28 (3rd edition): Kepler's $3/2$ is a scaling exponent of dynamics, this paper's $3/2$ is the solution of a dimensional equation, and all they share is the form "the square root of a cube". Scope: a structural interpretation of established physical law (Layer 2). No new physical law and no prediction is claimed.

Positioning of this paper (discipline): This paper offers a **structural interpretation** of established physical law. It claims neither the discovery of new physical laws nor the proof of open problems. The algebraic relations presented are substitutions into known expressions; the aim is to propose a geometric reading of them. No claim contradicting established theory is made. **The appearance of the same number in several contexts is not treated as evidence of a common origin** (Papers 48, 86, 100, 115).

Note on units (important): The substitutions $G = 4\pi$, $\hbar = \frac{1}{4\pi}$ employed here constitute a **choice of natural units**. G and $\hbar$ are dimensionful quantities whose numerical values depend entirely on the unit system. Setting $G = 4\pi$ is possible in exactly the sense that $G = 1$ (geometrised units) or $G = 6.674 \times 10^{-11}$ (SI) is possible; **physics does not determine which is "correct"**. What this paper exhibits is therefore **how the equations look once this unit system is adopted**, not a new fact about nature. The relations obtained hold in natural units, and **conversion factors are required to carry them into SI**.

1. Introduction: how many degrees of freedom did $\hbar G = 1$ spend?

Earlier editions recorded that under $G = 4\pi$ and $\hbar = \frac{1}{4\pi}$ the product $\hbar G = 1$ cancels and the Planck length may be written $l_p = c^{-3/2}$. **The substitution is correct.**

But saying "a choice of units was made" is not enough. Paper 38 (3rd edition) showed that, since there are only three base dimensions M, L, T , at most three dimensionful quantities may have their values assigned independently, and that a fourth becomes a claim about nature rather than a convention.

So one must count.

This paper imposes values on G and $\hbar$ — two of the three.

2. The substitution and its consequences

Theorem 2.1 (The cancellation $\hbar G = 1$ and the Planck length)

Under $G = 4\pi$ and $\hbar = \frac{1}{4\pi}$,

$$\hbar G = \left(\frac{1}{4\pi}\right)(4\pi) = 1, \quad l_p = \sqrt{\frac{\hbar G}{c^3}} = \sqrt{\frac{1}{c^3}} = c^{-3/2}.$$

The substitution is correct. The sections below write out **what this expression spends and what it leaves unspent**.

3. Counting the degrees of freedom — this expression still has one left

Established Fact 3.1 (Every triple is dimensionally independent)

With base dimensions (M, L, T) , the dimension exponents of the four quantities are

$$\hbar : (1, 2, -1), \quad G : (-1, 3, -2), \quad c : (0, 1, -1), \quad m : (1, 0, 0).$$

For each of the four ways of choosing three of them, the determinant of the exponent matrix is non-zero:

Triple	det	Verdict
$(\hbar, G, c)$	2	independent (Planck units)
$(\hbar, G, m)$	1	independent
$(\hbar, c, m)$	1	independent
(G, c, m)	1	independent (the basis of Paper 38)

Hence whichever three are chosen, a suitable choice of the units (M, L, T) assigns them arbitrary values simultaneously.

Corollary 3.2 (A fourth assignment is not a convention)

There are **four** quantities $\hbar, G, c, m$ but only **three** base dimensions. At most **three** may have their values assigned independently, and **imposing a value on a fourth is not a choice of units but a claim about nature** (Paper 38, 3rd edition).

Concretely: if this series adopts $m = 4\pi$ (Papers 18, 38), $G = 4\pi$ (Paper 35) and $\hbar = \frac{1}{4\pi}$ (this paper), then $(\hbar, G, m)$ exhausts the budget, and the numerical value of c can no longer be chosen — it is determined.

Conversely, adopting $(\hbar, G, c)$ is precisely Planck units, so **the unit of mass is fixed to be the Planck mass**, and $m = 4\pi$ becomes **a claim rather than a convention**.

Either is permissible; both together are not.

Observation 3.3 ($l_p = c^{-3/2}$ leaves one degree unspent)

This paper assigns values to only **two** quantities, G and $\hbar$. That is exactly why l_p remains a function of c .

Spending the last degree on $c = 1$ gives

$$l_p = 1^{-3/2} = 1,$$

that is, **the Planck length becomes the unit of length** — not a new result but **the definition of Planck units**.

That $l_p = c^{-3/2}$ "still contains c " is not a defect: it is the display of a budget with one item remaining.

4. The exponent 3/2 is the output of solving a dimensional equation

4.1 Solving it

Writing $l_p = \hbar^a G^b c^d$ and matching dimensions,

$$a(1, 2, -1) + b(-1, 3, -2) + d(0, 1, -1) = (0, 1, 0) \quad (\text{a length}).$$

The M component gives $a = b$, the T component gives $d = -3a$, and the L component gives $2a + 3a - 3a = 2a = 1$.
Hence

$$(a, b, d) = \left(\frac{1}{2}, \frac{1}{2}, -\frac{3}{2}\right), \quad l_p = \hbar^{1/2} G^{1/2} c^{-3/2} = \sqrt{\frac{\hbar G}{c^3}}.$$

Quantity	a ($\hbar$)	b (G)	d (c)	Closed form
Length l_p	1/2	1/2	-3/2	$\sqrt{\hbar G/c^3}$
Time t_p	1/2	1/2	-5/2	$\sqrt{\hbar G/c^5}$
Mass m_p	1/2	-1/2	1/2	$\sqrt{\hbar c/G}$
Energy E_p	1/2	-1/2	5/2	$\sqrt{\hbar c^5/G}$

Corollary 4.1 (There is no dynamics in the $3/2$)

The triple (a, b, d) above is the unique solution of a 3×3 system of linear equations. All that enters is the dimensions of $\hbar$, G and c ; no equation of motion and no orbit appears.

The $3/2$ of the Planck length is the closing of a dimensional ledger.

4.2 Why the square roots? Because the largest invariant factor is 2

Theorem 4.2 (The origin of the half-integer exponents)

Let A be the dimension-exponent matrix of $(\hbar, G, c)$; then $|\det A| = 2$. For an integer matrix A ,

$$A^{-1} = \frac{\text{adj}(A)}{\det A},$$

and the entries of $\text{adj}(A)$ are integers; hence the denominators of the entries of A^{-1} divide $|\det A| = 2$. That, however, is an upper bound and not an equality ($\text{diag}(2, 2)$ has $|\det| = 4$ and yields halves only; Paper 149).

The denominator that actually occurs is the largest invariant factor d_n , and the invariant factors of this A are $(1, 1, 2)$, so $d_n = 2$ (the cokernel is $\mathbb{Z}/2$). Indeed the rows of A^{-1} are $(\frac{1}{2}, -\frac{1}{2}, \frac{1}{2})$, $(\frac{1}{2}, \frac{1}{2}, -\frac{3}{2})$ and $(\frac{1}{2}, \frac{1}{2}, -\frac{5}{2})$.

That the exponents of the Planck length, time, mass and energy are without exception half-integers — and therefore that every quantity in Planck units is written with a square root — is a consequence of that largest invariant factor being 2. The cokernel of this A being cyclic, $|\det A|$ and d_n agree.

Observation 4.3 (Change the basis and the kind of exponent changes)

The basis (G, m, c) used in Paper 38 (3rd edition) has invariant factors $(1, 1, 1)$. Here $|\det| = 1$, and an upper bound of 1 forces the largest invariant factor to be 1 as well, so the entries of the inverse are integers, and indeed:

Quantity	G	m	c	Closed form
Length	1	1	-2	Gm/c^2 (the gravitational-radius form)
Time	1	1	-3	Gm/c^3
Mass	0	1	0	m
Energy	0	1	2	mc^2

Not one square root appears. With (G, m, c) as basis the natural energy is mc^2 itself (Paper 12) and the natural length is Gm/c^2 .

The impression that "Planck units are full of square roots" is not a property of nature but a property of the determinant of the chosen basis.

5. Calling the roll of 3/2 — an addition to Paper 28 (3rd edition)

The second edition withdrew the first edition's identification of this paper's 3/2 with that of Kepler's third law. That judgement was correct. The 3rd edition gives the distinction a name, in the vocabulary of Paper 28 (3rd edition).

Non-integer number	What it is	Origin
1.26... (Koch curve)	Fractal dimension	Hausdorff dimension (Paper 94)
3/2 (Kepler)	Scaling exponent of dynamics	the inverse-square law forced by Gauss's flux in 3D (Paper 28, 3rd ed.)
3/2 (this paper)	Solution of a dimensional equation	the unique solution of a 3 × 3 linear system (no dynamics)

Corollary 5.1 (Same number, different roots)

Kepler's $3/2$ is a scaling law in a **variable** (the semi-major axis a): change a and T changes, and the relation is **testable**. Indeed, from Mercury to Saturn, $T/a^{3/2}$ lies between **0.999** and **1.001**:

Planet	a [AU]	T [yr]	$T/a^{3/2}$
Mercury	0.387	0.241	1.0010
Venus	0.723	0.615	1.0004
Earth	1.000	1.000	1.0000
Mars	1.524	1.881	0.9998
Jupiter	5.203	11.860	0.9993
Saturn	9.537	29.450	0.9999

By contrast, the c carrying this paper's $3/2$ is a **constant**. Since there is no operation of "varying c ", **this is not a scaling law and there is no data against which to test it**.

All they share is the form "the square root of a cube". An agreement of form must not be read as an identity of phenomenon (Papers 86, 100, 101).

Corollary 5.2 (The table supplies five confirmations, not six)

One astronomical unit is the Earth's semi-major axis, and one year is the Earth's orbital period. The a and T of the Earth row are therefore **the units themselves**, and $T/a^{3/2} = 1/1 = 1$ holds exactly, and by convention. **That row cannot possibly fail.**

Hence **the Earth row is a convention rather than a fact** (Papers 95 and 35, 3rd edition), and **the independent confirmations this table supplies number five**.

This is the discipline established elsewhere in this series applied to its own table. A convention must not be counted among the confirmations.

Observation 5.3 (How to read the residuals — printing noise against a real deviation)

The entries are computed from inputs of three or four significant figures. The relative sensitivity of $T/a^{3/2}$ is

$$\frac{\delta(T/a^{3/2})}{T/a^{3/2}} = -\frac{3}{2} \frac{\delta a}{a},$$

so rounding in the last printed digit of a alone ($\delta a \simeq 5 \times 10^{-4}$) produces a variation of $\sim 1.9 \times 10^{-3}$ for Mercury and $\sim 1.0 \times 10^{-3}$ for Venus. **The wobble visible among the inner planets lies inside the band created by the printing precision.**

That Jupiter and Saturn both fall below 1, by contrast, is not explained by rounding (Jupiter's rounding sensitivity is only $\sim 1.4 \times 10^{-4}$). The exact two-body problem gives $T^2 = a^3/(1 + m/M)$, hence

$$\frac{T}{a^{3/2}} = \left(1 + \frac{m}{M}\right)^{-1/2},$$

and the mass ratios predict ≈ 0.9995 for Jupiter and ≈ 0.99986 for Saturn; **the direction agrees with the table in both cases.**

This paper does not, however, treat that as a verification. The input precision of the table is comparable to the effect, and the mutual perturbations of Jupiter and Saturn are large. **It is recorded as a remark only.**

6. The 4π inside $\hbar = \frac{1}{4\pi}$ is not an independent occurrence

The number 4π recurs throughout this series. **But the 4π inside $\hbar = \frac{1}{4\pi}$ does not belong to that company.**

Corollary 6.1 (It is merely the reciprocal of G)

The value $\hbar = \frac{1}{4\pi}$ was **chosen so that $\hbar G = 1$** . Once $G = 4\pi$ has been fixed, wanting $\hbar G = 1$ leaves no option other than $\frac{1}{4\pi}$.

This 4π therefore carries no information whatsoever beyond the choice of G . It has nothing to do with a **forced 4π** such as that of Poisson's equation (Gauss's flux; Root 1 of Paper 35, 3rd edition), and **must not be counted as " 4π appearing in $\hbar$ as well"**.

The cancellation occurred because it was arranged to occur.

Incidentally, in this unit system $\hbar = 2\pi\hbar = \frac{2\pi}{4\pi} = \frac{1}{2}$. That 2π is **Root B (periodicity of phase)** of Paper 18 (3rd edition), of different origin from the 4π inside $\hbar$.

7. The Planck length is not a minimum length

The first edition introduced the Planck length as "what is taken to be the minimum length in quantum gravity" and called it a "minimum UI pixel size". **That the latter is a name and not a derivation was already recorded in the second edition.** The 3rd edition adds a caution about the former.

Observation 7.1 (No established theory states a minimum length)

The claim that the Planck length is a lower bound on length is not part of established physics. The Planck length is **the scale at which quantum-gravitational effects are expected to stop being negligible**, and its provenance, as seen above, is **dimensional analysis**. Several theoretical frameworks incorporating a minimum length have been proposed, but **none is established**.

Corollary 7.2 (The Planck scale is a module boundary)

Paper 113 recorded that the **boundary between an older and a newer theory always lies where a dimensionless number crosses one**. The Planck scale is exactly that: **the place where the dimensionless ratio E/E_p reaches one**.

Paper 35 (3rd edition) said the same thing from the other side: in natural units $[G] = M^{-2}$, and **a coupling of negative mass dimension makes divergences worsen at higher orders** (pure gravity diverges at two loops; Goroff–Sagnotti 1986). **E_p is nothing other than the scale at which that perturbative expansion breaks down**.

The Planck length is therefore not "a pixel that cannot be subdivided" but "the boundary beyond which the present description stops working". The former is a claim; the latter is a known fact.

Personal reflection of the author (Layer 3; labelled non-scientific / no claim of mechanism)

When I first saw the cancellation $\hbar G = 1$ I felt I had discovered something. But once the 3rd edition did the accounting, it turned out that **the cancellation happened because I chose $\hbar$ so that it would**. The value $\frac{1}{4\pi}$ is nothing more than the reciprocal of 4π ; 4π did not "appear" there.

What surprised me more was **the reason Planck units are full of square roots**. I had felt it as an expression of the depth of quantum gravity. The answer was that **the determinant is 2**. Swap the basis for (G, m, c) and the determinant becomes 1, no square root survives — and the natural energy turns out to be mc^2 itself. **How the numbers look was decided by which three I picked**.

Still, learning that this series **exhausts its budget** with m , G and $\hbar$ was worth the trip. Should I ever wish to set one more quantity, that would no longer be a convention but a claim. **For the first time I can draw the line between where I am free and where I am responsible**. One stops at the edge of the cliff (Paper 101).

8. Scope / Conclusion

What is shown: that $G = 4\pi$ and $\hbar = \frac{1}{4\pi}$ give $\hbar G = 1$ and $l_p = c^{-3/2}$ (§2) / that **every triple among $\hbar, G, c, m$ is dimensionally independent** while at most three may be assigned, a fourth being a claim (§3) / that $l_p = c^{-3/2}$ leaves one degree unspent, and that spending it on $c = 1$ gives $l_p = 1$, the definition of Planck units (§3) / that the exponents $(\frac{1}{2}, \frac{1}{2}, -\frac{3}{2})$ are **the unique solution of a dimensional equation**, containing no dynamics (§4.1) / that **the half-integer exponents follow from $|\det| = 2$** , whereas (G, m, c) with $|\det| = 1$ yields integer exponents (§4.2) / that Kepler's $3/2$ and this paper's $3/2$ are **distinct roots** (§5) / that **the 4π in $\hbar = \frac{1}{4\pi}$ is merely the reciprocal of G** (§6) / and that the Planck scale is a **module boundary** (§7).

What is not shown (restraint): any identity with Kepler's third law (one is a scaling law in a variable, the other a power of a constant) / **that the Planck length is a minimum length** — no established theory says so / **the "minimum UI pixel size"** — a name, not a derivation / **no counting of $\hbar$'s 4π as a solid-angle 4π** / **no new fact about the Planck length / quantum gravity is not solved** (§7 only points at where the difficulty lives) / no new physical law and no prediction (Layer 2).

The main result is unchanged: under $G = 4\pi$ and $\hbar = \frac{1}{4\pi}$ one has $\hbar G = 1$ and $l_p = c^{-3/2}$.

What the 3rd edition adds is the accounting and the provenance. This expression spends **two of three** budgeted assignments, and spending the last on $c = 1$ returns $l_p = 1$ — the definition of Planck units. The exponent $3/2$ is **the solution of a 3×3 linear system**, with no dynamics in it.

The square roots of Planck units were a consequence of the determinant being 2.

**How the numbers look is settled by which three one chooses —
and one is allowed no more than three.**

Revision Record

4th edition (August 2026): No conclusion has changed. Following Paper 149, the origin of the half-integer exponents has been rewritten from “the determinant $|\det| = 2$ ” to “the largest invariant factor 2” (4.2, abstract). What $|\det|$ gives is an upper bound on what the denominator divides, not the denominator itself: $\text{diag}(2, 2)$ has $|\det| = 4$ and yields half-integers only. The invariant factors of $(\hbar, G, c)$ are $(1, 1, 2)$ and the cokernel is cyclic, so the conclusion of the 3rd edition — that the Planck exponents are half-integers — stands unchanged. Only the way the reason is written has been corrected.

3rd edition (August 2026): unified the notation of the title ($c^{-1.5} \rightarrow c^{-3/2}$) with the body and changed the subtitle to **the counting of degrees of freedom and the origin of the half-integer exponents**. Applied the theorem of Paper 38 (3rd edition) to show that every triple among $\hbar, G, c, m$ is dimensionally independent, that at most three may be assigned and a fourth is a claim, and that $l_p = c^{-3/2}$ leaves one degree unspent (§3). Derived the exponents $(\frac{1}{2}, \frac{1}{2}, -\frac{3}{2})$ as the unique solution of a dimensional equation (§4.1) and showed that the half-integer exponents follow from the determinant being 2, whereas the basis (G, m, c) with $|\det| = 1$ gives integer exponents and a natural energy of mc^2 (§4.2). Gave the distinction from Kepler a name in the vocabulary of Paper 28 (3rd edition) (§5). Made explicit that the 4π in $\hbar = \frac{1}{4\pi}$ is only the reciprocal of G and not an independent occurrence (§6). Added that the Planck length is not a “minimum length” but a module boundary (§7; Papers 113 and 35, 3rd edition). It further records as a corollary that the Earth row of the planetary table equals 1 by definition (one astronomical unit and one year are the Earth's own a and T), so that the independent confirmations number five, and adds an observation on how to read the residuals (the wobble among the inner planets lies inside the band created by the printing precision, while the systematic shortfall of Jupiter and Saturn agrees in direction with $(1 + m/M)^{-1/2}$ though it is not treated as a verification) (§5). The main results $\hbar G = 1$ and $l_p = c^{-3/2}$ are unchanged.

2nd edition (July 2026): withdrew the first edition's identification of this exponent with “the same rendering-lag exponent as Kepler's third law”. Kepler's $3/2$ is a testable scaling law in a variable ($T/a^{3/2} = 0.999\text{--}1.001$ from Mercury to Saturn), whereas the Planck length's $3/2$ is a power of the constant c and not a scaling law; all they share is the form “the square root of a cube”. The phrase “minimum UI pixel size” was likewise set aside as a name, not a derivation. First edition: Zenodo 10.5281/zenodo.21430490.

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