One Distinction: The Language of the Sciences Rewritten from a Single Definition

Method, results and limits of version 2.1

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Abstract

This essay reports the state of a book. The book is One Distinction (version 2.1). It rewrites the vocabulary of the sciences from one definition. The definition reads: a distinction is a movement that returns to itself. The distinction is at once the first mark. Nothing else is assumed.

The essay states the method. It lists what was proved or computed. It says which links to current science hold and which do not. Of 24 translation lines, one is kept as a structure link, five are partly kept, seven are defined, ten are readings and one is dropped. Of 63 field rows, one is kept, eight are partly kept, fourteen are defined, thirty-eight are readings and two are dropped. In the first round two of twelve locked predictions failed and one held only in part. In the second round all fourteen held. In the third round all seven numerical claims held. In the fourth round, on Chapter 21, seven of nine claims were confirmed and two in part. The round found flaws of wording and scope. They are repaired. The computations were checked by agents under a hash-locked protocol. The check is limited. The agents are Claude models. No physical value is derived and no physical prediction is made.

Keywords: distinction, closure, balanced ternary, cellular automaton, affine plane, translation key, bridge to current science.

1. Aim

The aim is a bridge. Scientists use words such as space, time, force and charge. Each word carries assumptions. The book asks what these words become if only one definition is kept. It then asks which parts of current science survive the rewrite.

The book does not test the definition against old science. Chapters 1 to 20 use no measured value. Chapter 21 adds one calibration, as a declared pin. The book uses no outside observer. It does not present a match of words as a derivation.

2. Starting point and rules

A movement has three states. It goes with the loop (+1), against it (−1) or not at all (0). Three steps in a row form a window. A window is closed if its steps sum to zero modulo three. Of the 27 windows, nine are closed. One is standing (0, 0, 0). Two are rings (three equal steps). Six hold all three steps.

A closure of depth 2 is three closed windows whose carries form a closed window. A closure of depth k + 1 is three closures of depth k in the same way. A seam joins two closures. Its residues are the sums of the windows that straddle the join. Its tension is the number of non-zero residues.

Five rules govern the book.

- Nothing enters from outside the definition, except one declared pin and the unit of length that rests on it (Chapter 21).
- A word of current science is kept only when a check in the net confirms a relation.
- A word whose meaning the book fixes is defined. No relation is claimed.
- A word with no check is a reading. A reading is not a proof.
- A measured value is never used as proof.

3. Method

Every result is proved or computed in the net. Ten programs carry the computations: closure.py, net2.py, bridgecheck.py, chemtest.py, bridge2.py, towers_free.py, round2.py, round3.py, pin_calc.py and pin_check.py. Counts that depend on a long computation are marked as such in the book.

The author has a protocol of his own. It is called the Respondent–Judge protocol. Its steps are these.

- Predictions are written and hashed (SHA-256) before the programs are written.
- Claims are written and hashed before any respondent sees them.
- A respondent receives only the claim text. It recomputes from the definitions.
- A judge writes its own test first. Only then does it read the respondent's report.
- The author recomputes and scores the predictions.

The respondents and the judges were Claude agents. They worked in separate directories. They are the same model family as the author's assistant. This limits the value of the check. Section 7 states how much.

4. Results

4.1 The net at depth 1 is a plane

Give each closed window the pair (first step, last step), read modulo three. The middle step follows. The nine windows then form the plane $GF(3)^2$, where GF(3) is the field of three elements.

The seam from A to B depends only on the difference B − A. This holds for all 729 triples. The tension of the seam is the number of non-zero coordinates of that difference. Each window has one partner with tension 0, four with tension 1 and four with tension 2. The tension is the same in both directions.

The symmetries of the net at depth 1 number 72. They are nine translations and eight signed swaps of the two coordinates. A brute-force search over all 362,880 permutations of the nine windows gave the same number.

The seam is not bilinear. For 648 of the 729 triples (A, B, C), the seam of A with B + C differs from the sum of the two seams. So the affine part of Grassmann's geometry fits at depth 1. His exterior product does not.

4.2 Passing

One round of passing replaces every step by the sum of itself and its two neighbours, modulo three. This is an additive cellular automaton over GF(3). Its polynomial is $x^{-1} + 1 + x$. Martin, Odlyzko and Wolfram studied such automata in 1984.

- After one round the sum of every loop is divisible by three. This holds for all loops of up to 12 steps.
- For loops of 3 steps, two rounds bring every loop to zero. For loops of 9 steps, five rounds do.
- For loops of 4, 8 and 12 steps, nine loops are reproduced by passing. For 9 steps, only the zero loop is.
- A loop is periodic if passing brings it back after some rounds. For n = u m steps, with u a power of three and 3 not dividing m, there are 3^{n-u} periodic loops. The rest is emptied. For n = 4 the periodic loops form nine fixed loops and nine cycles of length 2. For n = 5 they form the zero loop and ten cycles of length 8. The cycle lengths are computed, not derived.

The whole-number winding is not conserved. A loop's winding is the sum of its steps divided by three. Of the 6,561 closed loops of 9 steps, 4,016 change winding after one round. The

loop of nine steps of −1 goes from winding −3 to winding 0. What the net conserves is balance by place, modulo three.

A loop here is a sequence with a marked first step. Two sequences that differ by a rotation are two loops. Counted up to rotation, the numbers differ. The reading matters for the counts of 4.2. It does not matter for the sums or for the number of rounds.

4.3 The net at depth 2

There are 387 closures of depth 2. There are 57,068,937 at depth 3. Over the 149,769 ordered pairs of closures of depth 2, the tensions are these.

Tension	0	1	2	3	4
Ordered pairs	16,809	49,560	63,072	15,312	5,016

At depth 1 the tension of a seam is the same in both directions. At depth 2 it is not. For 89,568 ordered pairs the two directions differ. Direction is the first thing that depth 2 adds.

Closures fall into 81 classes of twins. Twins have the same seam to every closure. Fifty-one classes hold seven closures. Thirty hold one. Only four symmetries move classes at depths 2, 3 and 4: the identity, negation, reflection and their product. The program nauty found this at depths 2 and 3. A second program sorted the classes by refinement. After one class was fixed, every class held one member. That gave order 4 at depths 2, 3 and 4. Section 16.19 of the book now proves it for every depth from 2 on. At depth 1 there are 72 symmetries. A respondent and a judge in round 3 found order 4 at depths 2 to 6 by exact search.

4.4 Charge and valence

Each closure has a first and a last charge at every level. The charge is the sum of the residues of the inner windows. At depth 2, 51 closures have no charge. These are exactly the closures that join themselves with tension 0. A further 156 have one non-zero charge. And 180 have two. All charge sits at level 0.

Two closures that form a loop need not have opposite charges. Only 16,929 of the 149,769 ordered pairs do. One prediction expected otherwise. It failed.

A loop of closures in which every seam is free balances. The first charges sum to zero modulo three. So do the last charges. The charge is a list of digits, one per level. The net has no carry between levels. Three equal charges balance modulo three. As whole numbers they do not.

The book defines demand as the number of non-zero charges of a closure at a level. It defines a bond as a loop of closures in which the seams take up the charges. These are definitions. They give no charge to any real atom.

4.5 Chains of closures

A chain of m closures is a cyclic sequence of closures. A chain is free if every seam has tension 0. Let G(k) be the number of closures of depth k. Let F(k) be the number of ordered pairs of closures of depth k with a free seam. Then F(1) = G(1) = 9 and $F(k+1) = (F(k) - 2)(G(k) - 2)^4 + 2$.

Theorem. The number of free chains of m closures of depth k + 1 is $((F(k) - 2)(G(k) - 2))^m + 2$. For depth 2 this is $49^m + 2$.

The proof has three steps. Write each closure as three closures of depth k. A seam is free if the last part of the first closure and the first part of the next form a free pair of depth k. And all six parts carry one value c. Going round the chain, all parts carry the same c. If c is +1 or −1, every part is the ring. That gives two chains. If c is 0, the m free pairs are chosen independently, F(k) − 2 ways each. The middle parts are any closures that carry 0, G(k) − 2 ways each.

Depth	(F(k) − 2)(G(k) − 2)	m = 1	m = 2
2	49	51	2,403
3	6,470,695	6,470,697	41,869,893,783,027

A transfer-matrix program confirmed the formula for depth 2 up to m = 45 and for depth 3 up to m = 3. In version 1.7 only depth 2 was known, from an exact computation. Now the proof covers every depth.

At depth 1 no loop of windows has a total tension of 1. At depth 2 a chain can. The 156 closures with one non-zero charge are chains of one closure with total tension 1. One prediction expected otherwise. It failed. The charge inside a closure balances the single residue at its seam.

For total tension above zero a recursion gives every count at every depth (Theorem 16.23). At depth 1 the count has a closed form. The generating polynomial in z, where z marks tension, is $((1 + 2z)^m + 2(1 − z)^m)^2$. At depth 2 the transfer matrix has no such form. Its characteristic polynomial has irreducible factors of degree 4 and 5.

4.6 Words of motion

The book fixes what a few words of motion are in the net. A step is one movement. A place is the return point of a step. Change is the first difference of the steps. Second change is the second difference. Modulo three it equals the window sum. So tension is second change.

A word is straight if its second change is zero everywhere. The closed windows are exactly the nine words (s, s + d, s + 2d) modulo three. Acceleration is read as what does not close.

This is a reading. The book derives no mass, no force law, no uniform motion of a body, no three-dimensional space and no constant.

5. The bridge to current science

Appendix C of the book is a ledger. It gives the outcome of the check for every line of the translation key.

Outcome	Lines	Lines (words)
Kept	1	handedness
Partly kept	5	space; part and whole; measurement; interaction; conservation law
Defined	7	property; place; law of nature; information; number; resolution; sample size
Reading	10	thing; identity; time; cause; constant; equilibrium; level; observer; random; true and false
Dropped	1	subject, agent

The field chapters hold 63 rows. Appendix C lists all of them.

Outcome	Rows	Rows (words)
Kept	1	reaction
Partly kept	8	set; force and field; conservation; measurement; bond; cycle; budget; society as a sum

Outcome	Rows	Rows (words)
Defined	14	axiom; excluded middle; natural number; real continuum; binary base; valence; system boundary; average; environment; information processing; bit; program; simulation; storage
Reading	38	the rest, among them time, particle, constants, atom, organism, disease, mind, language, money
Dropped	2	absolute space; subject and predicate

Some checks are small. The nine closed windows give four sets, so a set loses the order that the closure keeps. Of the 27 windows, 18 are open, 7 closed and 2 carrying. Cutting a balanced-ternary word is rounding for all words of up to eight digits. Of the 729 triples of closures of depth 1, 387 close, so a whole is not any sum of parts.

Five researchers serve as bridgeheads. Martin, Odlyzko and Wolfram define additive cellular automata. The passing operator is one. This is a structure link. 't Hooft and Rowlands share the idea of a deterministic system of words underneath. This is a reading. Grassmann gives affine geometry. It fits at depth 1. Fox gives the three-colouring of knots. Its crossing rule, twice the over colour equals the sum of the two under colours, is the closed window. This holds for all 27 triples. The trefoil has nine colourings: three constant and six that read as the six closed windows with three different steps. This is a structure link. It does not make a particle a knot. Larson gives motion as the one primitive. His unit of speed is tied to a measured speed. The book does not use it.

6. The pin to measurement

Chapter 21 adds one calibration. It is declared and not derived. One step of depth 0 lasts T0 = 1.520655 × 10^-16 s. This is Larson's natural unit of time. Larson calculates it from the Rydberg frequency of hydrogen, counted in half-cycles. T0 is not a measured interval. Two declarations come with it. T0 is the duration of every step of every closure, and durations add. One step per T0 moves at the speed of light. That gives the length unit S0 = 4.558816 × 10^-8 m. It is Larson's second unit. It is 1.5 parts in a million above c T0, because Larson used a rounded c.

One winding of depth k then lasts 3^k T0. A measured duration has a position: its logarithm to base 3 over T0. The day sits at 43.50 and the year at 48.87. A light pulse of 43 as sits at −1.15. A pulse of 18 as, reported in 2026, sits at −1.94. The 43 as value is contested. A re-evaluation gives about 60 as or more. Positions below 0 come from the logarithm. The counts of the net stop at depth 0. T0 is a rod and not a floor. The book draws no conclusion from the fractional parts.

The pin derives no constant. It says nothing about which closure has which depth. It gives the net no space. It makes no prediction. Nothing in Chapters 1 to 20 is derived from it. The common rod of Declaration 1 sits beside the statement that each closure keeps its own count. The book says so in the places where that statement stands.

7. Independent check

The claims of the book were checked under the Respondent–Judge protocol of Section 3. There were four rounds. In rounds 1 to 3 the predictions were hashed first. The claims followed. In round 4 only the claims were hashed. Respondents recomputed from the claim text alone. Judges wrote their own tests before they read the respondents' reports. The author reran the programs.

Round 1 covered version 1.7. It checked 23 numerical claims and 7 literature claims. Respondents and judges agreed on all 23 numerical claims.

Round 2 covered version 1.8. Fourteen predictions were hashed first. All fourteen were right. Then nine numerical claims and 22 literature claims were hashed.

Group, round 2	Claims	Respondent	Judge
A. Windows, balanced ternary, closures, Fox rule, passing cycles, base 3	6	6 confirmed	6 agree
B. Free chains, four symmetries, tension counts	3	3 confirmed	3 agree
L. Literature	22	15 confirmed, 7 partly, 0 false	16 confirmed, 6 partly, 0 false; same verdict on 17 claims, a different label on 4

Round 3 covered version 1.9. Seven numerical claims about the new Sections 16.19 and 16.20 were hashed first. They cover tower counts, zeros, distinct rows, the group at depths 1 to 6, and chains at depths 1 to 3. A respondent confirmed all seven from the definitions alone. It counted all 57,068,937 closures of depth 3 directly. A judge made its own tests first, then checked each step of the two proofs. It found no false step. It found one wrong index, loose wording and clashes of symbols. These were repaired.

Round 4 covered Chapter 21 of version 2.0. Nine claims were hashed. No predictions were registered. Seven claims were confirmed: the tables, the positions, the SI and CODATA values, the 2017 pulse and the Julian year. Two were confirmed in part: the exact size of the shift of the positions when the Rydberg constant of an infinite nucleus replaces that of hydrogen, and the gloss on Larson's formula. The round also showed that shorter pulses were reported after 2017 and that the 43 as value is contested. The judge listed 17 flaws of wording and scope. The main ones: the chapter used two units of Larson and said one. T0 was called measured. S0 differs from c T0 by 1.5 parts in a million. The corollary held for whole steps only. The 43 as row was out of date. All are repaired in version 2.1. The repairs were not checked again.

Group B reached depth 4 for the symmetries and the tension counts. The chain formula was also proved for all depths. The judge re-derived the proof and found no gap. The four symmetries were found by two programs, one of them nauty. The symmetry group has order 4 at depths 2, 3 and 4. At depth 1 it has order 72.

The literature claims were weakened where the judges found them too strong. Seven statements changed. Brouwer, Primas and Woolley, Saussure, Whorf, Lakoff and Johnson, Mirowski, and Maturana and Varela against Rosen were reworded. Crowell and Fox (1963) is kept as the origin of three-colouring. It is not the source of the counts. The counts rest on Przytycki (1998).

The claim texts had flaws. The judges found them. The claim files stay locked by hash. The book was corrected instead.

- A loop is a sequence with a marked first step. Counted up to rotation, two counts of 4.2 change.
- The seam is an ordered list of residues. In the other order a claim fails for 54 of 81 pairs.
- Reflection means reversing the first three and the last three steps of the word. Reversing the whole word gives the tension of the opposite direction.
- In a claim on balanced ternary the order of the digits was not stated. The last digits are the least significant ones.

- A claim on the sets of windows gave sizes 1, 1, 1 and 6. Those are numbers of windows. The sets have 1, 1, 1 and 3 elements.
- The depth-4 count of closures rests on a recursion. It was not found by listing the closures.
- One title was wrong. The Marcer and Rowlands paper is titled Nilpotent Quantum Mechanics: Analogs and Applications.
- Modulo k applies to the coefficients of the polynomial. The polynomial itself is reduced modulo $x^N - 1$.
- At depth 2, charge at level 1 is zero because that level has only three units.

In round 1, nine of twelve predictions were right, two were wrong and one held in part. The first miss expected that two closures forming a loop have opposite charges. This holds at depth 1. At depth 2 only 16,929 of 149,769 ordered pairs do. The second miss expected that no chain has total tension 1. At depth 2, 156 chains of one closure do. The part-hit expected the number of free chains to exceed the number of neutral closures. It does for m of 2 or more. For m = 1 both are 51.

The check has limits. The respondents and judges are Claude agents. They share a model family with the author's assistant. They worked in separate directories and could not see each other. They may still share blind spots. The literature check used full texts for some sources and only summaries for others. The 't Hooft book was checked by publisher page and metadata only. The Larson sources were mostly seen as summaries. In round 2, the judge saw Crowell and Fox, Reidemeister, Dehn and Jones only through secondary sources, and Primas and Woolley through the Stanford Encyclopedia of Philosophy. No person has reviewed the proofs. No proof assistant has checked them. The depth 4 results rest on a derived structure that was tested on samples and on one word for each profile. Theorems for which no claim was written were not checked.

8. Limits and open problems

- The proofs of Theorems 16.22 and 16.23 were checked by one judge, a Claude agent. The irreducibility of the factors of degree 4 and 5 rests on one computer algebra system.
- Larson's unit of time is linked to closure depths by one declared pin. It rests on a calibration and on two declarations. Chapter 21 was checked once, in round 4. The repairs were not checked again. Larson's printed books were not read.
- Physics words are not derived: time, space, force, mass, constants.
- Results 7 and 8 of the book stay hypotheses. Result 8 does not hold in the net.
- Charge has no carry between levels. Whether a reading with a carry exists is open.
- The book does not say which closure is which atom.
- Thirty-eight of 63 field rows are readings.
- No human mathematician or domain expert has reviewed the book. The checks were made by Claude agents.

9. Conclusion

One definition yields a small, exact structure. At depth 1 it is a plane over three elements. At depth 2 it has direction, charge and a count of free chains. Part of this meets mathematics that already exists. Little of it reaches physics.

The bridge to current science is thin. It reaches measurement through one pin, which converts depth into seconds and metres. Most words stay readings. The ledger says which. A reader who disagrees with a line can argue about that line. The rest of the structure does not depend on it.

Annotated references

Each entry says what the source is and how this essay uses it. Entries also say what was read, so that a reader can continue from there.

Konstapel, J. (2026). The Vacuum.Net Theory: Foundations. Ninth Edition, v9.2. Leiden: Constable Research.

The full proofs of Results 1 to 8 are in Parts III to VII. Its Part I predates the minimal definition used here.

Konstapel, J. (2026). The Assumptions Nobody Declares. constable.blog, 26 July 2026.

A list of 58 assumptions of modern science. The book numbers the words of its translation key by this list.

Konstapel, J. (2026). One Distinction: The Language of the Sciences Rewritten to Fit the Minimal Definition of the Vacuum.Net Theory. Version 2.0. Leiden: Constable Research.

The book this essay reports on. Appendix B lists the status of every statement. Appendix C is the ledger of the key. The programs named in Section 3 belong to it.

Spencer-Brown, G. (1969). Laws of Form. London: Allen & Unwin.

Draw a distinction. The mark, re-entry, and the identity of distinction, mark and observer. The direct precedent of the definition. Read first for the idea.

Martin, O., Odlyzko, A.M. & Wolfram, S. (1984). Algebraic properties of cellular automata. Communications in Mathematical Physics 93, 219–258. doi:10.1007/BF01223745.

Additive cellular automata: configurations are polynomials, one step multiplies by a fixed polynomial, coefficients are taken modulo k and positions form a ring. An appendix gives the factorisation of $x^N - 1$ over a finite field, with repeated factors when the characteristic divides N. Agents read the full text in a re-typeset reprint, not in the journal pagination. The passing operator of Section 4.2 is such an automaton. Start here to compare the known theory with Section 4.2.

Lidl, R. & Niederreiter, H. (1997). Finite Fields. 2nd ed. Cambridge: Cambridge University Press.

Polynomials over a field of three elements and their factors. Background to the passing operator.

McKay, B.D. & Piperno, A. (2014). Practical graph isomorphism, II. Journal of Symbolic Computation 60, 94–112.

The program nauty. It computed the symmetry groups of the nets at depths 2 and 3 (Section 4.3). Section 16.19 of the book proves the result for every depth.

Knuth, D.E. (1997). The Art of Computer Programming, Vol. 2. 3rd ed. Reading, MA: Addison-Wesley.

Balanced ternary: every whole number has exactly one word of digits −1, 0, +1. The base of the charge digits in Section 4.4.

't Hooft, G. (2016). The Cellular Automaton Interpretation of Quantum Mechanics. Cham: Springer. Fundamental Theories of Physics 185. doi:10.1007/978-3-319-41285-6.

Open access. Presents quantum mechanics as a tool applied to a system that may be classical at its core. Only the publisher page was read, not the book. The essay claims a shared idea only: a deterministic system underneath. It makes no claim about quantum mechanics.

Rowlands, P. (2010). Physical interpretations of nilpotent quantum mechanics. arXiv:1004.1523.

Operators and wavefunctions whose square is zero. Agents read the full text. The author read the abstract and the opening pages. The essay makes no identification with the net.

Marcer, P. & Rowlands, P. (2017). Nilpotent quantum mechanics: analogs and applications. Frontiers in Physics 5, 28. doi:10.3389/fphy.2017.00028.

Describes a universal rewrite system: a scale-independent, fractal process that generates zero-totality alphabets. The authors say nilpotent quantum mechanics can be derived from it. The derivation is referred to their earlier work and no independent test is offered. Agents read the full text.

Crowell, R.H. & Fox, R.H. (1963). Introduction to Knot Theory. Boston: Ginn. Reprint: Springer, GTM 57, 1977.

Knot groups and the Alexander polynomial. The three-colouring rule of Fox appears in its exercises. Not read by the author or by the agents. The statement comes from Przytycki (next entry).

Przytycki, J.H. (1998). 3-coloring and other elementary invariants of knots. Banach Center Publications 42, 275–295. arXiv:math/0608172.

An elementary account of three-colouring. Colourings do not change under the three Reidemeister moves. The trefoil has nine, the unknot three. Agents read the paper. It credits Fox, who devised the idea in 1956.

Larson, D.B. (1979). Nothing But Motion. Portland, OR: North Pacific Publishers.

The universe as motion in discrete units, with space and time as reciprocal aspects. The author did not read this book in print. Chapter 13, on physical constants, was read in the web edition of the Reciprocal System Research Society (reciprocalsystem.org/books/nbm/13-physical-constants), through tools that return summaries. It gives the natural units used in Section 6. The wording of Postulate I was checked in a secondary source, RS2 Theory (rs-theory.github.io/RS2-Theory.pdf), which agents read in full.

Larson, D.B. (1986). Outline of the Deductive Development of the Theory of the Universe of Motion. Paper at the Eleventh Annual ISUS Conference, New York, 16 August 1986. Footnotes by B. Peret (2013). Public domain.

A short statement of the Reciprocal System. It identifies unit speed with the speed of light. Seen only through summaries. The essay takes two units from Larson, a time as a declared pin and a length that rests on it (Section 6).

Grassmann, H. (1844). Die lineale Ausdehnungslehre, ein neuer Zweig der Mathematik. Leipzig: Wigand.

Introduced the exterior product, antisymmetric for basis elements. Not read by the author. The facts about it come from the sources below.

O'Connor, J.J. & Robertson, E.F. Hermann Günter Grassmann. MacTutor History of Mathematics. mathshistory.st-andrews.ac.uk/Biographies/Grassmann/.

A biography. It gives Grassmann's rules for the exterior product and his work on linear independence and subspaces. Agents read the full page. It does not mention affine spaces.

nLab. Ausdehnungslehre. ncatlab.org/nlab/show/Ausdehnungslehre.

A reference entry. It says the 1844 book includes affine spaces, as a modern reading, and the exterior product. Read it with the next entry.

Greco, G.H. & Pagani, E.M. (2010). Reworking on affine exterior algebra of Grassmann, Peano and his school. arXiv:1002.4105.

A historical paper on an exterior algebra over an affine space, where points and vectors coexist. It says the 1844 edition builds such an algebra on points, with points and vectors distinct, and that Peano later gave the axiomatic form (vector as a difference of points, 1898). The author read the abstract. Agents read the full text.

Tiesinga, E., Mohr, P.J., Newell, D.B. & Taylor, B.N. (2021). CODATA recommended values of the fundamental physical constants: 2018. Reviews of Modern Physics 93, 025010.

Rydberg constant, proton–electron mass ratio and Bohr radius (Section 6).

Larson Research Center. The New Physics, scalar physics, page 11. lrcphysics.com/scalar-physics.

Says Larson obtains his natural units from the Rydberg constant and the speed of light. Read through a snippet. The primary text is Chapter 13 of Nothing But Motion (above).

Gaumnitz, T. et al. (2017). Streaking of 43-attosecond soft-X-ray pulses generated by a passively CEP-stable mid-infrared driver. Optics Express 25(22), 27506–27518.

Reports a pulse of (43 ± 1) as. Abstract only. The value is contested (Zhao et al., below).

Zhao, X., Wang, S.-J., Yu, W.-W., Wei, H. & Lin, C.D. (2019). Metrology of time-domain soft X-ray attosecond pulses and re-evaluation of pulse durations of three recent experiments. arXiv:1905.09526; Physical Review Applied 13, 034043.

Re-analyses three 2017 experiments. Finds durations longer than about 60 as. Abstract read. Use it before quoting a record duration.

Gao, J. et al. (2026). Nature Communications 17, 8810. doi:10.1038/s41467-026-76827-3.

Reports isolated pulses of 18 ± 2 as, claimed as the shortest characterised to date. The author read the abstract of a conference talk and a press report. Respondent and judge read a public copy.