

The Mathematics of Closure

A Map of Open Problems in the Vacuum.Net

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Version 1.0

Preface

This book does one thing. It generates mathematics from the closure rule of the Vacuum.Net theory. It then places the open problems of mathematics on the map that results.

The book does not prove open problems. No problem in it is solved by the theory alone. What the map does is different. It shows which open problems ask the same closure question. It shows which of them already has a solved sibling. And it shows where the method of that sibling points.

Three kinds of statement appear. Each is marked.

- **Proven** — a published theorem, accepted by the mathematical community.
- **Computed** — a result of an explicit enumeration, given with its bounds.
- **Reading** — a placement of a problem on the closure map. A reading orders. It does not prove.

The scope is fixed in advance. The book covers the seven Millennium Prize Problems, the four Landau problems, and fourteen further problems that are widely cited as central. Together that is twenty-five problems. The list is given in full in Appendix A.

Part I — Generating Mathematics from Closure

1. The rules

The Vacuum.Net theory starts from five rules.

1. There is one strand. Everything that differs arises from the way the strand meets itself.
2. A state persists only if it closes on itself. What does not close does not persist as a state.
3. The net keeps the orientation in which it was laid down. A twist can change it. It is not lost.
4. The properties of the net depend on the local state.
5. The same pattern returns at every scale.

From these rules come four forms. A **strand** is the net itself. A **winding** is a strand that returns to itself. A **knot** is windings that hold each other in three directions. A **mesh** is the opening between strands.

The book uses only these words for the net. Each mathematical object is read as one of these forms, or as a question about them.

2. Seven kinds of closure

Each rule yields a kind of closure. Each kind of closure is a branch of mathematics.

Closure in the net	Branch of mathematics
A winding, counted	the natural numbers
A winding with kept orientation: +1, 0, −1	the integers; balanced ternary
Two windings set against each other	fractions where they close; irrationals where they never close; continued fractions as near-closures
A winding not built from smaller closures	the prime numbers
Windings closing in three directions	geometry, topology, knot theory
Windings closing in two directions	dynamical systems, fractals,

One same closure at every scale	renormalisation
Closure that depends on local state	analysis, differential equations
Orientation kept under twist	symmetry, groups, chirality

The table has eight rows for seven kinds. The first two rows are one kind: counting, with and without orientation.

3. The closure condition

Every closure in this book has the same shape. Two windings run against each other. They return together, or they leave a remainder.

The remainder is the central quantity. Call it the **rest**. Where the rest is zero, the windings close exactly. Where it is small, they nearly close. Where it is large, they drift apart.

A simple example shows the shape. Take a winding of length 2 and a winding of length 3. After n turns of the first and k turns of the second, the rest is $2^n - 3^k$.

This number is never zero for $n, k > 0$. A power of 2 is even. A power of 3 is odd. The two windings never close exactly against each other. **Proven**, elementary.

The near-closures sit at the convergents of $\log_2 3$. The continued fraction is $\log_2 3 = [1; 1, 1, 2, 2, 3, 1, 5, 2, 23, \dots]$.

The convergents give the pairs $(n, k) = (2, 1), (3, 2), (8, 5), (19, 12), (65, 41), (84, 53), (485, 306), (1054, 665)$. At $(19, 12)$ the ratio $2^{19}/3^{12}$ is 0.98654. This is the Pythagorean comma. **Computed**.

The rest returns in every family of this book. It is the thread of the map.

4. The method

The method has four steps.

1. **Generate**. Enumerate the closures of a family of maps or structures.
2. **Order**. Sort the closures by their rest.
3. **Match**. Set each open problem against the closures it asks about.
4. **Lever**. Find a solved problem with the same closure. Its method is the first place to look.

The method orders a problem. It shows where the real work lies. It does not replace that work. Generation yields cases. An open problem concerns all cases, infinitely many. No enumeration covers them. That needs an argument that holds for every case at once.

Part II — The Families

The twenty-five problems fall into eight families. Each family asks one closure question.

5. The rest between windings

The question. How small can the rest between two windings become?

5.1 The Collatz problem

Statement. Take a positive integer. Halve it if even. Otherwise multiply by 3 and add 1. The conjecture says every start reaches 1.

Reading. A 2-winding (halving) runs against a 3-winding (times 3). In binary, halving is a free shift. In ternary, times 3 is a free shift. The map is the

meeting of the two registers.

A cycle with k odd steps and n halvings closes only if

$$x \cdot (2^n - 3^k) = S, \text{ with } S = \sum_i 3^{k-1-i} \cdot 2^{a_i}.$$

Here S collects the “+1” contributions, each carried forward. A cycle exists only where the “+1” steps absorb the rest exactly.

Computed. All cycles of $x \rightarrow ax + 1$ (odd) and $x \rightarrow x/2$ (even), for all starts with $|x| \leq 3000$:

a	cycle	n	k	rest $2^n - a^k$
3	1	2	1	+1
3	-1	1	1	-1
3	-5	3	2	-1
3	-17	11	7	-139
5	1	5	2	+7
5	13 and 17	7	3	+3
7	1	3	1	+1

All starts from 1 to 10^6 reach 1 under the map with $a = 3$. **Computed.**

Three of the four cycles at $a = 3$ sit at rest ± 1 . At $a = 5$, the extra cycles 13 and 17 sit where $2^7 = 128$ and $5^3 = 125$ nearly close. A small rest allows closure.

The cycle at -17 closes with rest -139. Large rests can therefore close too. Rest 1 is not the only door.

Solved sibling. Which powers of 2 and 3 differ by exactly 1? Mihăilescu proved in 2002 that the only consecutive perfect powers are 8 and 9 (the Catalan conjecture). With $3 - 2$ and $4 - 3$, these are exactly the rests ± 1 above. The rest-1 closures are fully classified. **Proven.**

What is open. Two parts. No positive cycle with rest larger than 1. No orbit that grows without bound.

Known progress. No non-trivial cycle with fewer than 69 rising runs exists (Simons and de Weger, 2005). Almost all orbits reach almost bounded values (Tao, 2019). All starts below 2^{68} reach 1 (Barina, 2021). **Proven / computed.**

Lever. A strong lower bound on $|2^n - 3^k|$ constrains every cycle. The abc conjecture (5.2) gives such a bound.

5.2 The abc conjecture

Statement. For coprime $a + b = c$, the product of the distinct primes of abc is rarely much smaller than c . Precisely: for every $\varepsilon > 0$, only finitely many triples have $c > \text{rad}(abc)^{1+\varepsilon}$.

Reading. The equation $3^k + \text{rest} = 2^n$ is an abc triple. The conjecture says the rest between two windings built from few primes cannot stay small. It is the general form of the Collatz rest question.

Solved sibling. Mihăilescu (5.1) settles the case where the rest is exactly 1.

Status. Mochizuki published a claimed proof in 2021, in the journal of his own institute. Scholze and Stix identified a gap in 2018. The gap is not resolved to the satisfaction of the wider community. Outside Kyoto the conjecture is treated as open.

Lever. Baker’s theory of linear forms in logarithms gives effective lower bounds for $|2^n - 3^k|$. These bounds are weaker than abc but proven.

5.3 Pillai’s conjecture

Statement. For each fixed c , the equation $a^x - b^y = c$ has only finitely many solutions in integers with $x, y \geq 2$.

Reading. The same rest question, with the rest fixed at c instead of 1.

Solved sibling. The case $c = 1$ is Mihăilescu. **Proven.**

What is open. Every $c > 1$.

6. Irreducible windings

The question. How do the windings that are not built from smaller closures lie among all windings?

6.1 The Riemann hypothesis

Statement. All non-trivial zeros of the zeta function have real part $\frac{1}{2}$.

Reading. The zeros measure how far the count of prime windings departs from its smooth expectation. Real part $\frac{1}{2}$ is the balance point. The hypothesis says the irreducible windings depart from the smooth count by no more than the square root of their number.

Solved sibling. The prime number theorem: the count of primes up to x is about $x / \ln x$. Hadamard and de la Vallée Poussin proved it in 1896, by showing no zeros lie on real part 1. **Proven.**

Known progress. The first 10^{13} zeros lie on the line (Gourdon, 2004).

Computed.

What is open. The whole strip between real part $\frac{1}{2}$ and 1.

6.2 Twin primes

Statement. There are infinitely many primes p with $p + 2$ also prime.

Reading. Two irreducible windings at the smallest possible distance.

Solved sibling. Bounded gaps. Zhang proved in 2013 that some gap below 7×10^7 occurs infinitely often. Maynard and the Polymath project lowered it to 246. **Proven.**

What is open. The step from 246 to 2.

6.3 Goldbach's conjecture

Statement. Every even number above 2 is the sum of two primes.

Reading. Every even winding splits into two irreducible windings.

Solved sibling. The weak form, every odd number above 5 as a sum of three primes. Helfgott proved it in 2013. **Proven.** The strong form holds up to 4×10^{18} (Oliveira e Silva and others, 2014). **Computed.**

What is open. Two primes instead of three, for all even numbers.

6.4 Legendre's conjecture

Statement. Between n^2 and $(n + 1)^2$ there is always a prime.

Reading. Every shell between two square windings holds an irreducible winding.

Solved sibling. Bertrand's postulate: between n and $2n$ there is always a prime. Chebyshev proved it in 1852. **Proven.**

What is open. The shell from n^2 to $(n + 1)^2$, which is far thinner than n to $2n$.

6.5 Primes of the form $n^2 + 1$

Statement. Infinitely many primes have the form $n^2 + 1$.

Reading. Irreducible windings that sit one step past a square winding.

Solved sibling. Infinitely many $n^2 + 1$ have at most two prime factors

(Iwaniec, 1978). **Proven.**

What is open. One prime factor instead of two.

7. Exact closure of parts on the whole

The question. Do the parts of a winding close exactly to the whole?

7.1 Odd perfect numbers

Statement. No odd number equals the sum of its proper divisors.

Reading. A perfect number is a winding whose sub-windings close exactly to the whole: $\sigma(n) = 2n$.

Solved sibling. Every even perfect number has the form $2^{p-1}(2^p - 1)$ with $2^p - 1$ prime. Euclid proved one direction. Euler proved the other. **Proven.**

Known progress. No odd perfect number lies below 10^{1500} (Ochem and Rao, 2012). **Computed.**

What is open. Every odd number above that bound.

7.2 The Birch and Swinnerton-Dyer conjecture

Statement. The rank of an elliptic curve equals the order of vanishing of its L-function at 1.

Reading. Rational points are closures on the curve. The rank counts independent windings among them. The conjecture says this count can be read from one analytic number.

Solved sibling. Fermat's Last Theorem, via the modularity of elliptic curves. Wiles proved it in 1995, with Taylor. **Proven.** For analytic rank 0 or 1, the conjecture itself holds (Gross and Zagier, 1986; Kolyvagin, 1989). **Proven.**

What is open. Rank 2 and above.

7.3 The congruent number problem

Statement. Decide which integers are areas of right triangles with rational sides.

Reading. An exact closure of three rational windings into a right angle.

Status. Tunnell gave a complete criterion in 1983. It holds unconditionally in one direction. The other direction depends on the Birch and Swinnerton-Dyer conjecture.

What is open. The same as 7.2.

8. Knots

The question. Which forms close in three directions, and is there a smallest knot?

8.1 The Yang-Mills mass gap

Statement. Quantum Yang-Mills theory exists on four-dimensional space and has a positive lower bound on the mass of its excitations.

Reading. In the net, a knot is mass. The question asks whether there is a smallest knot: a closure in three directions below which nothing closes.

Solved sibling. The Poincaré conjecture (8.3). Its method, geometric flow that smooths a form until its type shows, is the closest proven tool for classifying closures in three directions.

What is open. The existence of the theory with mathematical rigour, and the gap.

8.2 The Hodge conjecture

Statement. On a projective complex manifold, certain cohomology classes are combinations of classes of algebraic subvarieties.

Reading. Every closed form of the right type is built from closures that can be written down by equations.

Solved sibling. The Lefschetz theorem on $(1,1)$ -classes settles the case of divisors. **Proven.**

What is open. Higher codimension.

8.3 The Poincaré conjecture

Statement. Every simply connected closed three-manifold is a three-sphere.

Reading. A closure in three directions with no holes has one form.

Status. Proven by Perelman in 2002–2003, by Ricci flow with surgery. The Clay Institute awarded the prize in 2010. **Proven.** It is the solved member of this family.

8.4 Knot recognition

Statement. Can it be decided in polynomial time whether a knot diagram is the unknot?

Reading. Can it be checked quickly whether a winding is closed on itself without a knot?

Solved sibling. Unknot recognition lies in NP (Hass, Lagarias and Pippenger, 1999) and in co-NP (Lackenby). **Proven.** Lackenby announced a quasi-polynomial algorithm in 2021.

What is open. Polynomial time.

9. State that breaks

The question. Does a closure stay smooth, or does it break?

9.1 Navier-Stokes existence and smoothness

Statement. Do smooth solutions of the three-dimensional Navier-Stokes equations exist for all time, or can they blow up?

Reading. A flow is a closure whose properties depend on its local state. The question asks whether the state can concentrate until the closure breaks.

Status. OpenAI announced a blow-up construction on 8 September 2026, checked formally in Lean. Buckmaster and Alpöge reported related results hours earlier, mainly for the Euler equations. Both build on work by Córdoba and Martínez-Zoroa. The Clay Institute still lists the problem as active. Experts have not yet confirmed that the formal statement matches the prize problem.

Solved sibling. Blow-up for the three-dimensional axisymmetric Euler equations with boundary. Chen and Hou gave a computer-assisted proof in 2022. **Proven.**

What is open. Independent confirmation that the September 2026 construction meets the prize statement.

10. Finding versus checking

The question. Is finding a closure as hard as checking one?

10.1 P versus NP

Statement. Can every problem whose solutions can be checked quickly also

be solved quickly?

Reading. Checking a closure means following the strand and seeing it return. Finding a closure means producing a winding that is not yet there. The problem asks whether the second is as easy as the first.

Solved sibling. Primality is decidable in polynomial time (Agrawal, Kayal and Saxena, 2002). A question long thought to need search turned out to need only checking. **Proven.**

What is open. The general case.

Note. This problem stands at the centre of the map. Every other problem in this book is a search for a closure that can then be checked. Insight, in the sense of a whole that appears before its steps, is the finding side.

11. Windings that never close

The question. Do two windings close, ever?

11.1 The irrationality of $e + \pi$

Statement. Is $e + \pi$ irrational? It is not even known.

Reading. Two windings, each known never to close against the unit, set against each other.

Solved sibling. π is transcendental (Lindemann, 1882). $\zeta(3)$ is irrational (Apéry, 1978). **Proven.**

What is open. $e + \pi$ and $e \cdot \pi$. At least one of the two is transcendental.

Proven. Which one is not known.

11.2 Schanuel's conjecture

Statement. For n complex numbers that are linearly independent over the rationals, the field they generate together with their exponentials has transcendence degree at least n .

Reading. Independent windings and their exponentials leave at least as many non-closing directions as there were windings.

Solved sibling. The Lindemann-Weierstrass theorem, the case of algebraic inputs. **Proven.**

What is open. The general case. It would settle 11.1.

11.3 The normality of π

Statement. Does every digit block appear in the decimal expansion of π with the expected frequency?

Reading. A winding that never closes. Does it visit every mesh equally often?

Solved sibling. Almost every real number is normal (Borel, 1909). **Proven.**

What is open. Any specific constant such as π , e or $\sqrt{2}$.

12. The same closure at every scale

The question. Does the same closure return at every depth, and is the set it draws connected?

12.1 Local connectivity of the Mandelbrot set (MLC)

Statement. The Mandelbrot set is locally connected.

Reading. The set of parameters whose orbit stays bounded. The conjecture says its boundary has no infinitely fine break at any scale.

Solved sibling. Feigenbaum universality, the same ratio at every period

doubling. Lanford gave a computer-assisted proof in 1982. **Proven.** Yoccoz proved local connectivity at all parameters that are not infinitely renormalisable. **Proven.**

What is open. The infinitely renormalisable parameters: exactly where the same closure returns at every depth.

13. Remaining problems of the scope

Three problems of the scope complete Appendix A. They sit in the families above.

- **The Hadwiger-Nelson problem** (Section 8, knots). How many colours does the plane need so that no two points at distance 1 share a colour? The answer lies between 5 (de Grey, 2018) and 7. **Proven.**
- **The Erdős-Straus conjecture** (Section 7, exact closure). Every $4/n$ is a sum of three unit fractions. It holds up to 10^{17} (Salez, 2014). **Computed.**
- **The Lonely Runner conjecture** (Section 11, windings that never close). Runners with distinct speeds on a circular track each become lonely at some time. Proven for up to seven runners (Barajas and Serra, 2008). **Proven.**

Part III — What the Map Yields

14. Each family has a lever

Every family contains a solved member. The solved member shows a method that worked for the same closure.

Family	Solved member	Method
Rest between windings	Catalan (Mihăilescu)	cyclotomic fields
Irreducible windings	prime number theorem, weak Goldbach, bounded gaps	analytic number theory, sieves
Exact closure of parts	even perfect numbers, Fermat	modularity
Knots	Poincaré (Perelman)	Ricci flow
State that breaks	Euler blow-up (Chen and Hou)	computer-assisted proof
Finding versus checking	PRIMES in P	polynomial identity testing
Windings that never close	Lindemann, Apéry	transcendence theory
Same closure at every scale	Feigenbaum (Lanford), Yoccoz	renormalisation

15. Connections the map makes visible

Collatz and abc. The cycle condition of Collatz contains the abc triple $3^k + \text{rest} = 2^n$. A proof of abc bounds the rest from below for every cycle. This connection is known in the literature. The map finds it without searching.

Collatz and the comma. The near-closures of Collatz are the convergents of $\log_2 3$. The pair (19, 12) is the Pythagorean comma. The tuning problem in music and the cycle problem in arithmetic read the same number.

Pillai, Catalan and Collatz. All three ask about the rest between powers. Catalan fixes the rest at 1 and is solved. Pillai fixes it at c and is open. Collatz lets the “+1” steps absorb it and is open.

Birch-Swinnerton-Dyer and congruent numbers. One closure question in two forms. A solution of the first settles the second.

Schanuel and $e + \pi$. A solution of the first settles the second.

P versus NP and every other problem. Every open problem in this book is a closure that has not been found. Each would be checked quickly once found.

16. Status ledger

Problem	Family	Status October 2026
Collatz	rest	open
abc	rest	claimed (Mochizuki); not accepted
Pillai	rest	open for $c > 1$
Riemann	irreducible	open
Twin primes	irreducible	open; gap ≤ 246 proven
Goldbach (strong)	irreducible	open; weak form proven
Legendre	irreducible	open
$n^2 + 1$	irreducible	open
Odd perfect numbers	exact closure	open
Birch-Swinnerton-Dyer	exact closure	open; ranks 0 and 1 proven
Congruent numbers	exact closure	conditional on BSD
Erdős-Straus	exact closure	open
Yang-Mills	knots	open
Hodge	knots	open
Poincaré	knots	proven (Perelman)
Unknot recognition	knots	open in polynomial time
Hadwiger-Nelson	knots	open; between 5 and 7
Navier-Stokes	state	claimed (OpenAI, September 2026); not confirmed
P versus NP	finding	open
$e + \pi$	never closing	open
Schanuel	never closing	open
Normality of π	never closing	open
Lonely Runner	never closing	open in general; proven up to seven runners
MLC	every scale	open at infinitely renormalisable parameters

Twenty-four rows. The twenty-fifth problem of the scope is the strong form of the Riemann hypothesis for all L-functions. It belongs with 6.1 and has the same status.

Problems solved by the Vacuum.Net theory alone: none. Problems placed on the closure map: twenty-five of twenty-five. Families with a solved member: eight of eight.

Appendix A — The scope

The seven Millennium Prize Problems: Birch-Swinnerton-Dyer, Hodge, Navier-Stokes, P versus NP, Poincaré, Riemann, Yang-Mills.

The four Landau problems: Goldbach, twin primes, Legendre, $n^2 + 1$.

Fourteen further problems: Collatz, abc, Pillai, odd perfect numbers, congruent numbers, Erdős-Straus, unknot recognition, Hadwiger-Nelson, $e + \pi$, Schanuel, normality of π , Lonely Runner, MLC, generalised Riemann hypothesis.

Appendix B — Computation

All cycles of $x \rightarrow ax + 1$ (x odd) and $x \rightarrow x/2$ (x even) were enumerated for $a = 1, 3, 5, 7$ and all starts with $|x| \leq 3000$, with an orbit cut-off at $|x| = 10^{12}$. For $a = 3$, all starts from 1 to 10^6 were followed to 1. The continued fraction of $\log_2 3$ was computed to ten terms in double precision.

Appendix C — Annotated references

Mihăilescu, P. (2004). Primary cyclotomic units and a proof of Catalan's conjecture. *Journal für die reine und angewandte Mathematik* 572, 167-195. Why read? It closes the rest-1 case of every power question in Section 5. Reading advice: the introduction states the result in one page.

Simons, J. and de Weger, B. (2005). Theoretical and computational bounds for m -cycles of the $3n + 1$ problem. *Acta Arithmetica* 117, 51-70. Why read? It uses the convergents of $\log_2 3$ to exclude Collatz cycles. It is the closest published form of Section 3.

Tao, T. (2022). Almost all orbits of the Collatz map attain almost bounded values. *Forum of Mathematics, Pi* 10, e12. Why read? The strongest known result on Collatz orbits. Reading advice: the blog post of September 2019 gives the idea first.

Barina, D. (2021). Convergence verification of the Collatz problem. *The Journal of Supercomputing* 77, 2681-2688. Why read? The current computational bound, 2^{68} .

Scholz, P. and Stix, J. (2018). Why abc is still a conjecture. Manuscript. Why read? The precise location of the gap in the claimed proof.

Helfgott, H. (2013). The ternary Goldbach conjecture is true. arXiv:1312.7748. Why read? The solved member of the Goldbach problem.

Zhang, Y. (2014). Bounded gaps between primes. *Annals of Mathematics* 179, 1121-1174. Why read? The first finite bound on prime gaps.

Maynard, J. (2015). Small gaps between primes. *Annals of Mathematics* 181, 383-413. Why read? A simpler and stronger route to bounded gaps.

Wiles, A. (1995). Modular elliptic curves and Fermat's Last Theorem. *Annals of Mathematics* 141, 443-551. Why read? The method behind the exact-closure family.

Perelman, G. (2002-2003). The entropy formula for the Ricci flow and its geometric applications; Ricci flow with surgery on three-manifolds. arXiv:math/0211159, math/0303109. Why read? The solved member of the knot family.

Chen, J. and Hou, T. (2022). Stable nearly self-similar blowup of the 2D Boussinesq and 3D Euler equations with smooth data. arXiv:2210.07191. Why read? The solved sibling of Navier-Stokes.

Quanta Magazine (8 September 2026). AI has solved one of math's \$1 million Millennium Prize Problems. Why read? The account of the September 2026 Navier-Stokes claim and its open questions.

Agrawal, M., Kayal, N. and Saxena, N. (2004). PRIMES is in P. *Annals of Mathematics* 160, 781-793. Why read? A search problem that turned out to be a checking problem.

Tunnell, J. (1983). A classical Diophantine problem and modular forms of weight $3/2$. *Inventiones Mathematicae* 72, 323-334. Why read? The congruent number criterion and its dependence on BSD.

Yoccoz, J.-C. (1990s), as presented in Hubbard, J. H. (1993). Local connectivity of Julia sets and bifurcation loci: three theorems of J.-C. Yoccoz. In *Topological Methods in Modern Mathematics*. Why read? The proven part of MLC.

Lanford, O. (1982). A computer-assisted proof of the Feigenbaum conjectures. *Bulletin of the AMS* 6, 427-434. Why read? Universality at every scale, proven.

de Grey, A. (2018). The chromatic number of the plane is at least 5. *Geombinatorics* 28, 18-31. Why read? An amateur result on a long-open problem.

Konstapel, J. (2026). Vacuum.Net Theory: hoe massa, energie en ruimte één net vormen. constable.blog, 28 September 2026. Why read? The five rules from which Part I starts.

Clay Mathematics Institute. The Millennium Prize Problems. claymath.org. Why read? The official statements of the seven problems.