

Physics 2.0

Formalisation and Physlib: a synergy between AI,
mathematics and physics

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Advances in AI

july 2026

The Jacobian conjecture

Keller, 1939. Counterexample in $\mathbb{C}^3$.
Alpoge, with Claude Fable 5

august 2026

Ten open problems

From maths and CS
OpenAI “Astra”

september 2026

Navier–Stokes problem

Finite time blow-up.
AI models

october 2026

372 problems

OpenAI, internal model



section 1 of 6

Problems



The problem

Truth

Trust

Community

Recognition

Conclusion

Some of the problems we face

- 1 AI is starting to do tasks humans used to do.
- 2 AI is starting to scope human-led efforts at an unprecedented scale.
- 3 New inequalities are forming around AI access.
- 4 Current systems of recognition are not suited to this.

The conclusion of this

Physics 1.0 no longer works.

What are we going to do about it?

“Optimism is a duty. The future is open.”

— Karl Popper

It is our duty as academics to be optimistic about the future, and to push academia to a place where it can best serve the needs of humanity in this new world.

The goal of this talk

To convince you that a solution for the future exists.

Things to preserve: four tenets of academia

Truth

Trust

Community

Recognition

Physics 1.0

truth

Disseminated in academic papers.

trust

Peer review.

community

Spends its time writing papers, and reviewing them.

recognition

Citation counts, and numbers of papers.



section 2 of 6

Reorganising truth

The problem

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Conclusion

Do we want to keep academic papers?

Do we want to keep academic papers?

My answer: **No.**

What is wrong with papers?

- 1 Hard to find information.
- 2 Hard to reuse.
- 3 Hard to find connections.
- 4 AI can write them, read them and review them.

Pull towards structured data

The Protein Data Bank

AlphaFold

Show structured data is beneficial for AI.

Ingredient 1 of Physics 2.0

Replace papers with a **structured, open-source, community-run** corpus of knowledge.

Good news, this exists...



leanprover-community / Physlib

A community-driven corpus of knowledge of results from physics.

public
lean 4

★ 786 stars 🔗 205 forks 👤 114 contributors ⌚ started 2024

Dissent against our solution

- 1 Such a corpus of knowledge is hard to maintain.
- 2 It is hard to keep up to date.

AI helps with **all of this.**



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Adjusting trust

The problem

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Peer review

Do we want to keep peer review?

Peer review

Do we want to keep peer review?

My answer: **Absolutely**. However...

...there are problems with peer review

- 1 It does not scale efficiently with AI.
- 2 Mistakes get into papers, and slip past reviewers.

A solution exists

Combine **peer review** with **automated checks on correctness** through **formalisation**.

T

Technical interlude

What is an interactive theorem prover?

A programming language in which you can write mathematical definitions, theorems, and their proofs, with mathematical **correctness** and **consistency** guaranteed.

What is formalisation?

The process of writing results into an **ITP**.

The four main interactive theorem provers

Rocq

**Isabelle/
HOL**

Lean

Agda

This talk is in **Lean**.

A rapid overview of Lean

Proof compiler

Definitions, theorems, proofs

→ **consistency & correctness, guaranteed**

Built on type theory

Lean knows the **type** of everything, and checks that things have the type expected.

$$\underbrace{p}_{\text{proof}} : \underbrace{P}_{\text{theorem}} \quad \underbrace{7}_{\text{term}} : \underbrace{\mathbb{N}}_{\text{type}}$$

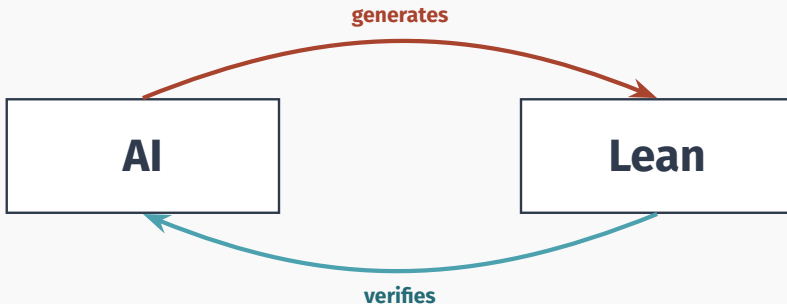
An example

```
def energy (m v : Real) : Real :=
  m * v ^ 2 / 2
```

```
theorem energy_nonneg
  (m v : Real) (hm : 0 <= m) :
  0 <= energy m v := by
  unfold energy
  positivity
```

Open this example in the live editor

The formalisation–AI loop



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End of technical interlude

How good is AI-driven formalisation now?

It can essentially formalise **anything you want**.

Anthropic's Claude formalised Fermat's Last Theorem in Lean in about eleven days, on Lean's three standard axioms alone and with no sorrys.

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Anthropic's Claude formalised Fermat's Last Theorem in Lean in about eleven days, on Lean's three standard axioms alone and with no sorrys.

However, this does not necessarily mean **well**.

Formalisation does not give you complete trust

Formalisation is not the whole picture, and should not give you the whole trust. For that you also need peer review.

Fermat's Last Theorem, made trivial

```
-- "the integers"
def MyInt : Type := Empty

def add (a b : MyInt) : MyInt :=
  Empty.elim a
def pow (a : MyInt) (n : Nat) : MyInt :=
  Empty.elim a

theorem flt (a b c : MyInt)
  (n : Nat) (hn : 3 <= n) :
  Ne (add (pow a n) (pow b n)) (pow c n) :=
  Empty.elim a
```

Lean accepts it. Nothing here is about numbers.

Ingredient 2a of Physics 2.0

The **corpus of knowledge** for physics should have content which is **formally verified**, where possible.

a dual process

Lean verification

the mathematics

and

Human review

the physics context, style, organisation
and quality

Good news, this exists...



leanprover-community / Physlib

A community-driven corpus of knowledge of results from physics, **formalised into Lean 4** where possible.

public
lean 4

★ 786 stars 🔗 205 forks 👤 114 contributors ⌚ started 2024

...built for the whole physics community

a choice of starting point

There is no single correct axiomatisation, so we allow a **choice of starting point.**

Physlib is one of three main ones



leanprover-community /

mathlib4

The math library of Lean 4.

★ 4,309 🔗 1,768

👤 798 🕒 2021



leanprover-community /

Physlib

Physics, digitalised into
Lean. Community-driven.

★ 786 🔗 205

👤 114 🕒 2024



leanprover /

CSLib

The computer science
library of Lean.

★ 754 🔗 214

👤 50 🕒 2025

Evidence that this can be done at scale and works

Top-level directories of PhysLib/, by lines of Lean.

Relativity	27,545	StatisticalMechanics	2,449
QFT	20,162	ProbabilisticTheory	2,306
Particles	19,104	Cosmology	1,858
SpaceAndTime	16,069	Meta	1,773
Mathematics	15,795	FluidDynamics	1,361
QuantumMechanics	13,057	CondensedMatter	1,003
ClassicalMechanics	11,784	ClassicalFieldTheory	554
Electromagnetism	9,442	Thermodynamics	432
StringTheory	5,285	Optics	48
Units	4,076	LatticeQFT	22

154,125 lines of Lean across **619** files.

Evidence that this can be done at scale and works

The Higgs boson, in Lean

live.lean-lang.org

The problem

Lean verification takes the mathematics. But part of the trust still rests on **human review** — and that **cannot scale**.

Ingredient 2b of Physics 2.0

There is another solution to scaling trust: **one-look review**, similar to the arXiv.

PhyslibAlpha

This is **PhyslibAlpha**, and it allows things to **scale**.

Project structure

upstream Mathlib

core

Physlib

Curated to a high standard for long-term reuse.

rapid

PhyslibAlpha

Lighter review, for large-scale AI-assisted contributions.

qi

QuantumInfo

Quantum information theory, being brought closer to Physlib.

adjacent CSLib

Additional benefits of having Physlib

- 1 Allows verification of results, both human and AI.
- 2 Allows easy reuse, and improvement.
- 3 Allows assumptions to be tracked.
- 4 Allows one to easily explore and constrain model spaces.
- 5 Prevents bit-rot: one corpus, kept compiling.
- 6 Avoids duplicated work, and definitions that are incompatible with one another.
- 7 AI speed and efficiency makes this feasible.



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Community

The problem

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Community

What will the community do now in this world?

Community

What will the community do now in this world?

My answer: They will **not** write and review papers.

As mentioned earlier

Writing papers, and reviewing for journals, is exactly the work that AI is now **capable of**.

Ingredient 3 of Physics 2.0

They will **build, maintain, review** and **grow** the corpus of knowledge (Physlib).

Examples of activities

Review

Maintenance

Refactoring

**Foundational
work**

Formalisation

Documentation

Extending

**Adding
experiments**

Building tools

Overcoming difficulties in formalising physics

- 1 Validation does not come with the guarantees of verification.
- 2 One physical concept, many mathematical descriptions.
- 3 Physics papers aren't written as definitions and theorems.
- 4 How physical assumptions enter.

Good news, people are already doing this.

100+

contributors

7

maintainers

**Always looking
for more**



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Recognition

The problem

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Papers and citations

Will people still get recognition based on papers and citations alone?

Papers and citations

Will people still get recognition based on papers and citations alone?

My answer: Of course **not**.

The problem with current recognition

Recognition is currently based only on **publishing papers** and **citations**.

In this new world that is a **poor proxy** for the work that actually matters — because it is precisely the work we have seen AI is **very capable of**.

Ingredient 4 of Physics 2.0

Recognition will be given to the work which **actually matters** in this new world.

Good news, the infrastructure exists.

contributions.physlib.io

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Sections

- I. Review** — For reviewing other people's pull requests to Physlib. (3 reports)
- II. Maintenance** — For keeping Physlib building and up to date. (3 reports)
- III. Refactoring** — For restructuring existing Physlib code so it is simpler or more general. (1 report)
- IV. Foundational Work** — For basic foundations that other parts of Physlib build on. (2 reports)
- V. Formalisation** — For adding new lemmas and definitions to Physlib or PhyslibAlpha. (2 reports)
- VI. Documentation** — For explaining Physlib: docstrings, module overviews, guides and tutorials. (0 reports)

New to Physlib?

Physlib is a library of physics written in the Lean 4 proof assistant. To start contributing:

- [Getting started with Physlib](#)
- [Good first issues](#)
- [Ask on Zulip](#)

Reviewing and maintenance are good ways to start contributing. Done regularly over a few months, they are also what most first reports are about.



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Conclusion

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Physics 2.0

truth

Papers → **Physlib**

trust

Peer review → **Lean + human review**

community

Writing papers → **Building and maintaining the corpus**

recognition

Citations → **Contributions recorded and verified**

Call to action

if you are hiring, or on grant committees

Start to recognise contributions to projects like **Physlib**, **Mathlib** and **CSLib** on a par with papers.

if you are an expert in physics

Come to **Physlib**, help review, help push forward your area of expertise.

“Optimism is a duty. The future is open. It is not predetermined. No one can predict it, except by chance. We all contribute to determining it by what we do. We are all equally responsible for its success.”

— Karl Popper, *The Lesson of This Century*

Thank you for watching

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github.com/leanprover-community/physlib

contributions.physlib.io

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