SHS Course

Philosophical Perspectives on the Exact Sciences I+II

Prof. Michael Esfeld*

Academic Year 2026–27

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The goal of this master programme is to acquire the skills necessary to address philosophical questions that arise from the exact sciences and their history. This includes questions such as:

- How do the visions of space and time change from Newton to Einstein?
- What is matter following the revolution brought about by quantum physics?
- What is a law of nature?
- Do mathematical objects really exist?
- Does artificial intelligence really think?

These questions, among many others, will be tackled in the philosophical and historical reflections on the exact sciences that this master module offers. These reflections provide intellectual tools for a better understanding of modern science and technology. After a series of introductory lectures, the students work in small groups of 2 to 5 people to prepare a philosophical essay on a topic from the philosophy or history of science. Students can freely choose their topic of interest – in coordination with a supervisor – but are encouraged to work on a philosophical project related to their field of study at EPFL.

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Contents

Part I.
Organization

1. Supervisors

Teaching assistant for this course is Amine Rusi (amine.rusielhassani@unil.ch). He is at your disposal for any questions regarding the course and will supervise most of the projects. The second teacher and supervisor of projects is Dr. Cristian Lopez (cristian.lopez@unil.ch). He will be supervising projects on philosophy of time, and philosophy of mathematics.

2. The Programme

The goal of the master programme is to acquire the skills necessary to address the philosophical questions that are raised by the exact sciences and their history. You choose a project and work in groups of *2–5 students*. By the end of the autumn term, you prepare an essay plan and defend it in a short presentation. During the spring term, you write an essay following your plan. You can freely choose among the projects proposed in Part II of this manual or choose a topic of your own in consultation with the supervisor. You are welcome to choose a topic that discusses philosophical issues in your field of study at EPFL. We propose projects in the following seven fields:

- Philosophy of space and time,
- Philosophy and History of Quantum Physics,
- Philosophy of Mathematics,
- Philosophy of Mind,
- Philosophy of Computer Science and AI.

If you wish to work on a topic that is not listed in this manual, please contact Amine Rusi.

3. What You Are Expected to Do

1. Follow the introductory lectures starting on 9 September 2026.
2. Find a group and a project by 19 October 2026.
3. Submit an essay plan at least 7 days before the oral presentation.

4. Present your essay plan in a short presentation (approx. 15 min. talk + 15 min. discussion) at the end of the autumn term.

5. Submit a first complete version of the essay by 1 May 2027.

6. Submit final version of the essay, after receiving feedback on the first draft, by 1 June 2027.

3.1. The Essay Plan

The essay plan is intended to help you prepare your essay. It should comprise 600–800 words (excluding references) written in complete sentences. It should include

1. the working title of your essay,

2. your names,

3. the last date when you revised the essay plan,

4. an introduction,

5. your research question(s),

6. how you're going to address the question(s), and

7. a list of references.

Send your essay plan to your supervisor at least 7 days before your oral presentation. The preferred format is PDF. You can write the essay plan in English or French and, depending on the supervisor, also in German. The oral presentations of the plan will take place in December (exact schedule will be announced). You may use electronic slides (e.g., PowerPoint).

3.2. Grading autumn term

You will receive a grade for the autumn term based on the submitted essay plan and the oral presentation, including the discussion. You don't have to master all the details of your topic as this will probably be your first encounter with philosophy of science. But we expect you to outline a clear and convincing project and demonstrate an understanding of the most important aspects of the topic and philosophical questions you are going to address.

3.3. The Essay

Target

You write a philosophical essay that should be understandable for a reader with basic knowledge in the respective field. The essay *can* include a technical part but *must* address a philosophical question. Technical terms or results requiring more than basic knowledge should be explained to the reader. You are not expected to produce original results, but demonstrate a good understanding of the essay topic and your own reflections about it.

Language

You may write your essay in English, French or German, although English is recommended. Since almost all the relevant publications are in English, this will make it easier for you to work with references and allow you to practice scientific writing.

Regardless of the language you choose, proper style and spelling are important. We take into consideration that you may not be writing in your native tongue, but clear and precise formulations matter in philosophical writing.

Structure

Your essay should include the following elements:

- title,
- names of the authors,
- date of last update,
- abstract ($\leq$ 150 words),
- word count,
- main text (introduction, core sections, conclusion),
- bibliography.

The abstract should briefly summarize the main content and results of your paper. The main text consists of several sections. The first section is always an introduction to the topic. After the introduction, you present your investigation into the respective topic, relying on pertinent literature to develop arguments and work out possible answers to the central research questions. Papers in philosophy and in the natural sciences can differ in this respect. For philosophical papers, it is considered good practice to present different opposing positions and discuss the respective arguments and counter-arguments. However, you should not remain "neutral". Evaluate the arguments critically and don't be afraid to state and defend your own position, as this usually makes your paper more interesting and original. The last section should summarize the main conclusions of your paper. Try not to be too repetitive but focus on the more novel results,

interesting ideas, or open questions arising from your discussion. In the end, your essay should look like a professional research paper in the philosophy of physics, mathematics, or artificial intelligence.

Length

The maximum word count depends on the number of authors contributing to your essay:

- 2 authors: 5000–6000 words,
- 3 authors: 6000–7500 words.
- 4/5 authors: 8000 words.

The word count includes everything in the main text, headings, quotes and footnotes, but not the abstract and bibliography. This should be an indicative length; students are welcome to write longer essays if appropriate. Every member of the group is expected to make a substantial contribution to the final essay.

Citations

Please use an *author-year citation format* (e.g., APA, Chicago, or Harvard). Do not reference publications by numbers or abbreviations. Complete and precise references are important. Material copied from other sources without proper attribution constitutes plagiarism.

Grading

We will grade your essay based on the following criteria:

- Did you develop clear/interesting/compelling arguments?
- Did you consider relevant literature?
- Does your essay satisfy the formal requirements (e.g., correct citation)?
- Is your essay written in a good style and correct language?
- Is your essay written concisely?

Submission

Please send a complete version of your essay to your supervisor by **1 May 2027**. We only accept PDF or Word documents. Please use the official cover page that you can download from the website of the SHS programme. You will receive feedback on this submission and have the chance to make corrections. The final version that will be graded is due on **1 June 2027**.

One-term projects

Under certain circumstances (e.g., for exchange students visiting EPFL for a limited time), it is possible to attend only part I of the course and complete the essay in one semester. Please e-mail Amine Rusi in case you take the course only in the autumn term.

4. Schedule

Autumn Term '26

The autumn term is divided into three parts:

1. Lectures

Location: Room INR 219, Wed 16h15-18h45.

Wed 9 Sept.:
16h15-17h30: Michael Esfeld: Introduction to the programme and Descartes on modern science
17h45-18h45: Cristian Lopez: Physics and philosophy

Wed 16 Sept.:
16h15-17h30: Michael Esfeld: Newton on natural philosophy
17h45-18h45: Amine Rusi: Philosophy of space and time

Wed 23 Sept.:
16h15-17h30: Michael Esfeld: Quantum physics: non-locality and the measurement problem
17h45-18h45: Michael Esfeld: The ontology of quantum physics

Wed 30 Sept.:
16h15-17h30: Amine Rusi: Philosophy of artificial intelligence and consciousness
17h45-18h45: Michael Esfeld: Mind and free will

Wed 7 Oct.:
16h15-17h30: Cristian Lopez: Mathematical structure and ontology
17h45-18h45: Amine Rusi: How to write an essay

Wed 14 Oct.:
16h15-17h30: Michael Esfeld: What is a law of nature?
17h45-18h45: Michael Esfeld: The scientific and the manifest image of the world

2. Preparation of the Essay Plan

- No lectures until the presentations.
- Definite fixing of the groups and essay topics by **19 October**.
- At least one meeting with your supervising assistant, further meetings upon request. Meetings can be scheduled via email.
- Submit the essay plan to your supervising assistant at least one week before your presentation.

3. Presentations

Presentations of essay plans: 15 minutes presentation (PowerPoint) + 15 minutes discussion. There will be four sessions on Wednesdays, 16h15-19h15, on

- 25 November,
- 2 December,
- 9 December,
- 16 December,

The exact presentation schedule will be posted on Moodle.

Spring Term '27

During the spring term, you are supposed to work on your essay. There will be no lectures, but you are required to *meet your supervisor at least twice* to discuss your project. We also recommend that you have regular contact with the other members of your group to discuss your topic and coordinate your work.

Starting from the beginning of the spring term, you will be able to schedule meetings with your supervisor via Moodle. Further meetings are available upon request. Submit a first complete draft of your essay by **1 May 2027**, and meet with your supervising assistant in May to discuss the results. If changes are requested, submit a revised and final version by **1 June 2027**.

5. How to Write an Essay?

Style

Writing is a skill that you can only achieve through regular practice and proper teaching. Before preparing your essay, please read the guidelines on writing a paper by the philosopher Jim Pryor from NYU. If you're interested in improving your writing skills in general, Sword (2012) is a good reference for academic writing.

Spelling and Punctuation

The English language has its own rules of punctuation. Good punctuation gives a clear structure to your text and helps the reader to grasp the correct meaning of a sentence. Trask (1997) is a primer on English punctuation. Good online dictionaries are for example:

- the Oxford Dictionary of English (ODE),
- the Oxford Advanced Learner's Dictionary (OALD).

The OALD uses easier explanations and contains simpler examples. Also, a thesaurus can be very helpful for improving your vocabulary. The ODE contains a huge database of synonyms. Software like *Grammarly* or the spell check in *Microsoft Word* can help you find and correct mistakes in grammar in spelling.

References

Esfeld, Michael. 2017. *Philosophie Des Sciences. Une Introduction.* Lausanne: Presses polytechniques et universitaire romandes.

Trask, Robert Lawrence. 1997. *The Penguin Guide to Punctuation.* London: Penguin.

6. Online Resources

To get an overview of your research topic, we strongly recommend that you start by consulting one of the following online encyclopedias of philosophy:

- The Internet Encyclopedia of Philosophy (IEP). (Introductory level)
- Routledge Encyclopedia of Philosophy (REP) (Introductory level).
- The Stanford Encyclopedia of Philosophy (SEP) (Advanced level).
- Scholarpedia (General science encyclopedia).

The SEP, in particular, is a comprehensive and widely-used encyclopedia containing articles on a wide range of philosophical topics. It is also a good starting point for finding further references. The IEP articles are also very helpful and usually more accessible. Scholarpedia contains many good entries on topics from physics.

We strongly recommend that you do not use other online sources unless you have discussed them with your supervisor. Many websites contain imprecise or even incorrect information. In particular, Wikipedia is not a scientific resource. While it can be useful for obtaining a quick overview of a topic or keyword, the quality of its articles varies, and most do not meet scientific standards.

7. A Note on the Use of AI Tools

The use of artificial intelligence tools—such as ChatGPT or other generative systems—is increasingly common in academic settings. While these tools can assist in brainstorming, summarising, or refining ideas, their use must be approached with transparency and integrity.

Important: Submitting work generated (in whole or in part) by AI without explicit mention is considered a form of *plagiarism*. If you have used such tools during any part of your writing process, you must:

- Clearly indicate which parts were assisted or generated by AI;
- Take full responsibility for verifying the accuracy and coherence of the content;
- Ensure that all final submissions reflect your own understanding and engagement with the material.

Unacknowledged use of AI tools may lead to academic consequences as per university policy.

This course encourages critical thinking, and that includes reflecting on the tools we use to produce ideas.

Part II. The Projects

Below, we propose a number of topics that are relevant to the contemporary discourse in philosophy and well suited for a two-term project. You can also choose any of the "propositions de travail" included in the textbook "Philosophie des sciences. Une introduction" by Michael Esfeld (Michael Esfeld. 2017. *Philosophie Des Sciences. Une Introduction.* Lausanne: Presses polytechniques et universitaire romandes). The second part of this book is a primer on many of the topics stated below. If you want to work on a different subject not mentioned in the book or this manual, you can formulate your own research topic in consultation with your supervisor.

8. Philosophy of Science and Metaphysics of physics

8.1. What Is a Law of Nature?

Fundamental physics studies the laws of nature. But what exactly are "laws of nature"? The great debate in contemporary philosophy of science is roughly between the "regularity view" and the "governing view" of laws. The first, also known as *Humeanism* or

the *Best System Account*, holds that laws are merely descriptive, an efficient summary of contingent regularities that we find in the world. The opposing, anti-Humean views, hold that laws do actually govern or guide or produce what happens in the world. One important elaboration of the governing view is called dispositionalism and holds that there exist fundamental (causal) properties in the world that determine the behavior of matter.

Suggested References

Michael Esfeld and Dirk-André Deckert. 2017. *A Minimalist Ontology of the Natural World.* Routledge. Section 2.3

Marc Lange. 2002. *An Introduction to the Philosophy of Physics: Locality, Fields, Energy, and Mass.* Oxford: Blackwell. Chapter 3

Barry Loewer. 1996. "Humean Supervenience." *Philosophical Topics* 24:101–127

Barry Loewer. 2012. "Two Accounts of Laws and Time." *Philosophical Studies* 160:115–137

Tim Maudlin. 2007. *The Metaphysics Within Physics.* Oxford: Oxford University Press. ISBN: 978-0-19-921821-9

9. Philosophy of Space and Time

9.1. The Nature of Space and Time: Substantivalism, Relationalism, and Super-Substantivalism

During the years 1715 and 1716, Leibniz and Clarke (writing on Newton's behalf) exchanged a series of philosophical, scientific, and theological letters on the nature of space and time. The Leibniz–Clarke correspondence, as it is known, established the contemporary debate on the nature of spacetime in the philosophy of physics and the metaphysics of science. Three approaches can be distinguished: relationalism, substantivalism, and super-substantivalism. *Relationalism* holds that space and time reduce to temporal and spatial relations among substances (e.g., particles), and that space and time do not exist on their own. *Substantivalism* holds that space and time are irreducible and exist on a par with matter. *Super-substantivalism* holds that there is no matter, but only space and time. Although many physical theories seem to support substantivalism, new relational formulations of classical mechanics, general relativity, and quantum mechanics have been developed in recent years, keeping the philosophical debate open.

Suggested References

Earman, J. 1989. *World enough and space-time. Absolute versus relational theories of space and time*. Cambridge (Massachusetts): MIT Press.

Benovsky, J. 2010. "The relationalist and substantivalist theories of time: foes or friends?" *European Journal of Philosophy*, 19 (4): 491-506.

Pooley, O. 2013. Substantivalist and relationalist approaches to spacetime, In Batterman, R. (Ed.), *The oxford handbook of philosophy of physics* (pp. 522-586). Oxford: Oxford University Press.

Dasgupta, S. 2015. "Substantivalism vs. Relationalism about space in classical physics". *Philosophy Compass*, 10/9: 601-624.

Hoefer, C. 1996. "The metaphysics of space-time substantivalism". *The Journal of Philosophy*, vol. XCIII, n° 1: 5-27.

9.2. The Direction of Time

Philosophers and physicists have been discussing the nature of the direction of time for over a century. In the philosophy of physics, three approaches can be distinguished: primitivism, reductionism, and eliminativism. *Primitivists* believe that the direction of time is part of the fundamental furniture of the natural world and is therefore irreducible (e.g., it is an intrinsic property of the spatiotemporal structure). *Reductionists* believe that the direction of time is a second-order property of the natural world that can be reduced to non-temporal asymmetries (e.g., the increase of entropy together with a low-entropy initial condition). *Eliminativists* believe that the direction of time is unreal or illusory, despite the fact that time seems to be directed. Although many physical theories seem to support reductionism or even eliminativism, primitivism cannot be rejected on the basis of physics alone.

Suggested References

Albert, D. 2000. *Time and Chance*. Cambridge (Massachusetts): Harvard University Press.

Earman, J. 1974. "An attempt to add a little direction to 'The Problem of the Direction of Time'", *Philosophy of Science* 41, pp. 15-47.

Loewer, B. 2012: "Two accounts of law and time". *Philosophical Studies*, 160, pp. 115-137.

Maudlin, T. 2002: "Remarks on the passing of time". *Proceedings of the Aristotelian Society*, 102, pp. 237-252.

Price, H. 2012. "The flow of time", in Craig Callender (ed.), *The Oxford Handbook of Time, Oxford University Press.*

Savitt, S. 1995. *Time's arrow today.* New York: Cambridge University Press. (Introduction).

Online Lectures

- Time's Arrow and Entropy: Classical and Quantum by Joel Lebowitz.
- Introduction to Thermodynamics and Statistical Mechanics by David Albert.
- The Reversibility Objections and the Past Hypothesis by David Albert.
- The Epistemic and Causal Arrows of Time by David Albert.

9.3. Space-Time in General Relativity

Einstein's theory of general relativity is our current best theory of spacetime. Maudlin (2012) is good conceptual introduction that use only little mathematics. From there you can go in two directions. One problem is to analyze whether general relativity is committed to space-time as a substance (similar to Newton's absolute space) or to a relational space-time (in the tradition of Leibniz). Another question is whether there is some sort of indeterminism in general relativity. The *hole argument*, originally formulated by Einstein and discussed in detail by Earman (1987), plays an important role in both discussions.

Suggested References

John Earman and John Norton. 1987. "What Price Spacetime Substantivalism? The Hole Story." *The British Journal for the Philosophy of Science* 38 (4): 515–25

Robert Geroch. 1978. *General Relativity from A to B.* Chicago: The University of Chicago Press. Chap. 7 and 8

Carl Hoefer. 1996. "The Metaphysics of Space-Time Substantivalism." *The Journal of Philosophy* 93 (1): 5–27

Tim Maudlin. 1990. "Substances and Space-Time: What Aristotle Would Have Said to Einstein." *Studies in History and Philosophy of Science Part A* 21 (4): 531–61

Tim Maudlin. 2012. *Philosophy of Physics: Space and Time.* Princeton, NJ: Princeton University Press. Chapter 6

Online Lectures

Einstein's Discovery of the General Theory of Relativity by John Norton.

10. Philosophy of Quantum Physics

10.1. Bell's Theorem and Quantum Nonlocality

Bell's theorem shows that nonlocality is a physical feature of our world. This has been called "the most profound discovery in science" and it is indeed impossible to understand quantum mechanics without understanding nonlocality. Unfortunately, it is a historical fact that Bell's theorem has been misunderstood by many physicists, leading to heated controversies that persist to this very day.

Suggested References

John Stewart Bell. 2004. *Speakable and Unspeakable in Quantum Mechanics.* 2nd Ed. Cambridge: Cambridge University Press

Sheldon Goldstein et al. 2011. "Bell's Theorem." *Scholarpedia* 6 (10): 8378. https://doi.org/10.4249/scholarpedia.8378

Tim Maudlin. 2014. "What Bell Did." *Journal of Physics A: Mathematical and Theoretical* 47 (42): 424010. https://doi.org/10.1088/1751-8113/47/42/424010

Dustin Lazarovici et al. 2018. "Observables and Unobservables in Quantum Mechanics: How the No-Hidden-Variables Theorems Support the Bohmian Particle Ontology." *Entropy* 20 (5). https://doi.org/10.3390/e20050381

Travis Norsen. 2006. "EPR and Bell Locality." *AIP Conference Proceedings* 844:281–93. https://doi.org/10.1063/1.2219369

Online Lectures

- Spooky Actions At A Distance? by David Mermin.
- What Did Bell Really Say? by Jean Bricmont.

10.2. The Quantum Measurement Problem

Schrödinger's cat is not merely a funny story illustrating the weirdness of quantum physics. It is a formulation of the infamous *measurement problem* demonstrating the

inconsistency of standard quantum mechanics. Understanding the measurement problem and its possible solutions leads to precise interpretations of quantum mechanics that draw a clear and objective picture of the microscopic world.

Suggested References

Tim Maudlin. 1995. "Three Measurement Problems." *Topoi* 14 (1): 7–15

Erwin Schrödinger. 1983. "The Current Situation in Quantum Mechanics." In *Quantum Theory and Measurement,* edited by John Archibald Wheeler and Wojciech Hubert Zurek, 152–67. Princeton, NJ: Princeton University Press

Detlef Dürr and Dustin Lazarovici. 2020. *Understanding Quantum Mechanics: The World According to Modern Quantum Foundations.* Springer International Publishing

10.3. Interpretations of Quantum Mechanics

Quantum mechanics is an extremely successful physical theory, but what is the theory actually about? Nowadays, the old Copenhagen interpretation, based on a fundamental concept of "measurement" or "observation" and Bohr's mysterious "complementarity principle", is no longer taken seriously by the majority of physicists and philosophers of physics. Instead, there are several proposals on the table that ground the predictions of textbook quantum mechanics in a clear ontology and precise dynamical laws.

Suggested References

Travis Norsen. 2017. *Foundations of Quantum Mechanics: An Exploration of the Physical Meaning of Quantum Theory.* Undergraduate Lecture Notes in Physics. Cham, Springer International Publishing, 2017. https://doi.org/10.1007/978-3-319-65867-4

Detlef Dürr and Dustin Lazarovici. 2020. *Understanding Quantum Mechanics: The World According to Modern Quantum Foundations.* Springer International Publishing

Tim Maudlin. 2019. *Philosophy of Physics: Quantum Theory.* Princeton, Princeton University Press

11. Foundations of Modern physics

11.1. History and Foundations of Quantum mechanics

The development of quantum mechanics is very rich and stands as one of the most important scientific developments in the history of humanity. It underwent several phases, initiated by experimental results that could not be explained using classical physics, e.g., black body radiation and the hydrogen spectrum. Theoretical physicists tried to

develop physical principles to build the foundations of a new theory: from the adiabatic hypothesis to the correspondence principle, the Heisenberg uncertainty principle, and more. The development of these principles took many years and involved many debates between physicists at the time. Interestingly, the foundational principles of quantum mechanics are still debated today. This project consists of studying the development of quantum mechanics historically and analyzing the key physical principles that played a pivotal role in its evolution.

Suggested References

Van der Waerden, B. L. *Sources of Quantum Mechanics*. Mineola, NY: Dover Publications, 2007. Reprint of the 1967 edition.

A. Einstein, K. Przibram, and M.J. Klein. 2011. *Letters on wave mechanics: Correspondence with H. A. Lorentz, max planck, and erwin schrödinger*. Philosophical Library/Open Road. ISBN: 978-1-4532-0464-1. https://books.google.co.ma/books?id=ovau2UxBJhAC

Link with many major seminal papers on quantum theory

Werner Heisenberg. 1971. *Physics and Beyond: Encounters and Conversations*. Vol. 42. World Perspectives Series

11.2. History and Foundations of Special and General theory of relativity

The development of the special and general theories of relativity followed numerous historical steps and were both formulated by one man: Albert Einstein. In the development of these theories, Einstein conducted many thought experiments, reconsidered numerous established physical principles related to the foundational views on space and time, and his insights were an amalgamation of philosophical principles, physical principles, and intuition. Einstein was influenced by several philosophers, including Ernst Mach and Henri Poincaré, and criticized others, such as Emmanuel Kant, regarding their views on geometry. Studying the historical development of the relativity theories will provide students with a comprehensive understanding of the foundational principles and the debates surrounding them. This foundation will prepare them to engage in ongoing philosophical debates related to the theories.

Suggested References

Paul Arthur Schilpp. 2000. *Albert Einstein: philosopher-scientist* [in en]. OCLC: 46804779. New York: MFJ Books. ISBN: 978-1-56731-432-8

Albert Einstein and Edwin P. Adams. 2003. *The meaning of relativity* [in en]. OCLC: 56109489. London: Routledge. ISBN: 978-0-203-44953-0

Albert Einstein and Derek Raine. 2013. *Relativity.* Routledge

Hendrik Antoon Lorentz et al. 1952. *The principle of relativity: a collection of original memoirs on the special and general theory of relativity.* Courier Corporation

12. Philosophy of Mathematics

Brown (2008), Colyvan (2012), and Friend (2007) are excellent textbooks on philosophy of mathematics. You don't need prior knowledge of logic or calculus. Colyvan (2012) is the shortest one and provides a good overview on modern topics. Friend (2007) seems to be the easiest one, as she almost never uses mathematical formulas; she introduces the historical debates, as well as some recent topics. Brown (2008) introduces many new topics that are not covered by the other books. All three sources have excellent lists of bibliographies, which help you in finding supplementary literature.

12.1. Do Mathematical Objects Exist?

What are mathematical objects? Are they creations of the human mind or do they exist independently of us? Do mathematicians "discover" mathematical facts or rather "invent" them? What makes mathematical facts true in the first place, and how can we know about them? These questions are as old as mathematics itself and still relevant today. Influential positions include Platonism, Logicism, Structuralism, and Nominalism, but each account comes with different problems and challenges that are the subject of ongoing philosophical debates.

Suggested References

James R. Brown. 2008. *Philosophy of Mathematics: A Contemporary Introduction to the World of Proofs and Pictures.* 2nd ed. New York: Routledge

Mark Colyvan. 2012. *An Introduction to the Philosophy of Mathematics.* New York: Cambridge University Press

Michèle Friend. 2007. *Introducing Philosophy of Mathematics.* Stocksfield, UK: Acumen

Philip Kitcher. 1985. *The Nature of Mathematical Knowledge.* Oxford, New York: Oxford University Press. ISBN: 978-0-19-503541-4

12.2. The Success of Mathematics in the Natural Sciences

In a now-famous essay, Nobel Prize-winning physicist Eugene Wigner reflected on the "unreasonable effectiveness of mathematics in the natural sciences." This initiated a philosophical debate that persists to this day. Mathematics is not only the "language" of physics; it also plays a crucial role in the special sciences, from chemistry and biology to the social and economic sciences. How can these successes be explained, given that mathematics seems to concern purely abstract objects?

In 2015, the Foundational Questions Institute (FQXi) organized an essay contest "Trick or Truth: the Mysterious Connection Between Physics and Mathematics" aimed at top researchers in this field. There you can find some very good papers in addition to the references given below.

Suggested References

Eugene P. Wigner. 1960. "The Unreasonable Effectiveness of Mathematics in the Natural Sciences." *Communications on Pure and Applied Mathematics* 3 (1): 1–14

Alan Baker. 2005. "Are there Genuine Mathematical Explanations of Physical Phenomena?" *Mind* 114(454):223–238

Alan Baker. 2009. "Mathematical explanation in science." *The British Journal for the Philosophy of Science,* 60(3):611–633

Max Tegmark. 2008. "The Mathematical Universe." *Foundations of Physics* 38 (2): 101–150. https://doi.org/10.1007/s10701-007-9186-9

12.3. Geometry in Physics vs. Mathematics

Geometry, as understood in mathematics, is a purely logical framework, devoid of any connection to the physical world; it's a priori. This was the perspective upheld by Euclidean geometry. However, Riemann shifted the paradigm of geometry by emphasizing that it should be intrinsically linked to the physical world rather than existing solely as an a priori structure. Einstein took this idea even further, asserting that while geometry serves as a useful logical framework for physicists, every geometrical theorem should undergo empirical testing, making geometry akin to a natural science. This particular perspective on geometry played a pivotal role in guiding Einstein towards the development of his theories of relativity.

Exploring the contrasting views of geometry — as an a priori framework versus as a natural science — provides insights into the intricate relationship between mathematics and physics. This investigation opens the door to various intriguing philosophical questions concerning the interplay and relationship between these two fields.

Suggested References

Albert Einstein, Geometry and experience

Marco Giovanelli. 2014. "But one must not legalize the mentioned sin: Phenomenological vs. dynamical treatments of rods and clocks in Einstein's thought." *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics,* 48: 20–44.

13. AI and the Human Mind

This complex of topics breaks down into two basic, mirror-inverted questions: (1) Could AI realize crucial features of human mentality, namely human rationality and consciousness (Sec.13.2)? (2) Does the human mind work the way we know computers do (Sec.13.3) ? Although the two inquiries interrelate, it is wise to keep them apart for present purposes.

13.1. Will machines ever reach human intelligence?

An Artificial General Intelligence (AGI) is a computer program that can solve problems in whatever context. By contrast, to this day, only Artificial Narrow Intelligences (ANIs) have been created, which are able to learn and to answer to queries only in a specific and more or less narrow context. Recent developments in Deep Learning Algorithms like ChatGPT raise the hope that an AGI is not far off anymore; still, the human mind is the only general intelligence we know of with certainty. There is also a further worry over and above generality, namely that AIs could never understand things, which is why they have to make do with vast amounts of data: thus, even if an AI could be generated that exhibits human-like behavior because of the vast datasets it was trained on, there would still be the question of whether its inner workings really resemble human reasoning.

Can the fundamental issues about the generality of a computer intelligence be resolved by advances in technology? Even if this were possible, can a machine that works without understanding truly be called "intelligent"?

Suggested references

Stanford Encyclopedia of Philosophy: "Artificial Intelligence"

Internet Encyclopedia of Philosophy: "Artificial Intelligence"

Kreeft, Peter 2010. *Socratic Logic.* St. Augustine's Press, pp. 35-46 (good summary of Aristotelian epistemology)

Dreyfus, Hubert L. 1967. "Why Computers Must Have Bodies in Order to Be Intelligent". *The Review of Metaphysics*, Vol. 21, No. 1 (Sep., 1967), pp. 13-32

Fodor, Jerry A. 1987. "Modules, Frames, Fridgeons, Sleeping Dogs, and the Music of the Spheres." In *The Robot's Dilemma: The Frame Problem in Artificial Intelligence*, edited by Zenon W. Pylyshyn. Ablex Publishing.

Fjelland, Ragnar. 2020. "Why General Artificial Intelligence Will Not Be Realized." *Humanities and Social Sciences Communications* 7 (1): 1–9 (strongly suggested, lucid, concise and up-to-date overview). Online article.

Lowe, E.J., 2013. "Naturalism, Theism, and Objects of Reason". *Philosophia Christi* 15(1).

PhilPapers collection: "Can Machines Think?"

13.2. Could Computer Programs Become Conscious?

Films and literature teem with machines that virtually are or have become persons. Although being a person certainly involves more, it certainly involves being conscious, where for something to be conscious it means that it is "awake to the world", that there is "something it is like to be that thing". This project is about the question whether machines (in virtue of the computer programs running on them) could become conscious in that sense. The question cannot be answered without dealing with the nature and genesis of human consciousness: only if the latter is identical to or the result of physical processes can the former arise in machines. Strong versions of substance dualism deny this, however. This project will therefore delve into the metaphysics of consciousness and explore the viability of the extant main positions in this branch of philosophy.

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13.3. The human mind - computational or rational?

Our minds seem to be so unlike computers because we are not our thoughts; rather, we have thoughts and can see the rational connections between them, or the lack thereof. Computers, by contrast, are just "number-crunching" machines without consciousness or selfhood. Still, the increase of knowledge about the brain, in particular about the (probabilistic) logic-gate structure of synapses, as well as naturalism and anti-metaphysics in philosophy have led a number of philosophers to defend computationalism, the position that the human mind is just a very complex assembly of computations. Hilary Putnam (1960) thinks that the mind-body problem is wholly linguistic in nature and that the same issues about the mind arise equally in connection with machines capable of self-reporting. David Chalmers (2011) motivates computationalism differently: to him, only the phenomenal aspects of consciousness (the sense qualities, the "what it's like" aspects) are beyond computations; our behavior, by contrast, can wholly be explained through computational processes. The detractors of computationalism are many, and their arguments much more influential than the ones in favor of computationalism (to the extent that there are genuine arguments at all). John Lucas famously argued based on the Godel theorem that human reason transcends strict deductive logic (Lucas 1961, see also R. Penrose); John Searle holds that semantic understanding can never be done by an algorithm alone (Searle 1980). Even more decisively, if human reason can be shown to be immaterial, then no computer, no matter how sophisticated, could ever emulate it (Feser 2013).

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