SHS Course

Philosophical Perspectives on the Exact Sciences I+II

Prof. Michael Esfeld*

Academic Year 2024–25
Manual Version: August 16, 2024

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. Further teachers and supervisors of projects are

- Dr. Alin Cucu (Alin.Cucu@unil.ch) (Philosophy of mind, AI and free will)
- Dr. Cristian Lopez (cristian.lopez@unil.ch) (Metaphysics of physics, philosophy of time, 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:

- Metaphysics of Physics,
- 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 11 September 2024.

2. Find a group and a project by 16 October 2024.
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 2025.
6. Submit final version of the essay, after receiving feedback on the first draft, by 1 June 2025.

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 counterarguments. 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, Hardvard, ...). Don't reference publications by numbers or abbreviations. Complete and precise references are important. Citations that are not indicated as such (e.g., copying from the internet) constitute 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 2025**. 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 2025**.

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 '24

The autumn term is divided into three parts:

1. Lectures

Location: Room INR 219, Wed 16-19h.

Wed 11 Sept.:
16h15-17h30: Cristian López: Physics and philosophy
17h45-18h45: Amine Rusi: Philosophy of space and time

Wed 18 Sept.:
16h15-17h30: Michael Esfeld: Newton on natural philosophy
17h45-18h45: Michael Esfeld: What is a law of nature?

Wed 25 Sept.:
16h15-17h30: Alin Cucu: Philosophy of artificial intelligence and consciousness
17h45-18h45: Michael Esfeld: Mind and free will

Wed 2 Oct.:
16h15-17h30: Michael Esfeld: Quantum physics: non-locality and the measurement problem
17h45-18h45: Michael Esfeld: The ontology of quantum physics

Wed 9 Oct.:
16h15-17h30: Cristian López: Mathematical structure and ontology
17h45-18h45: Amine Rusi: How to write an essay

2. Preparation of the Essay Plan

- No lectures until the presentations.
- Definite fixing of the groups and essay topics by **Wednesday 16 October**.

– One compulsory meeting with your supervisor, further meetings upon request. Meetings can be scheduled via email.

– Submit the essay plan to your supervisor at least one week before your presentation.

3. Presentations

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

– 27 November,

– 4 December,

– 11 December,

– 18 December,

The exact presentation schedule will be posted on moodle.

Spring Term '25

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.

1. Intermediate session I in February and March.
2. Intermediate session II in April.
3. Final feedback in May.

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 2025**. Your supervisor will give you feedback. If your essay needs improvement, you can submit a revised and final version until **1 June 2025**.

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 you start by consulting one of the following philosophy online encyclopedia:

- The Internet Encyclopedia of Philosophy (IEP). (Introductory level)
- Routlege 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 not to use other online sources unless you arrange this with your supervisor. Many websites contain imprecise or even wrong information. In particular, Wikipedia is not a scientific resource! While it can be useful to get a quick overview of a topic or keyword, the quality of the articles varies and most do not meet scientific standards.

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.

7. Philosophy of Science and Metaphysics of physics

7.1. The Relation between Metaphysics and Physics

Since the work of Quine in the 50s, naturalism in metaphysics has been the rule. It basically claims that philosophy (and metaphysics in particular) should defer methodologically and ontologically to science (to physics in particular). This means that, on the one hand, metaphysics is not methodologically autonomous, but continuous to science; and, on the other, the content of metaphysical claims (e.g., what there is) should be strongly constrained by science (by physics in particular). This raises the following questions: What is the relation between metaphysics and physics? May there be a complementary relation between metaphysics and physics? May metaphysics be autonomous? If yes, to what degree? If not, does it mean that metaphysics ought to be eliminated in favor of physics? In the last years, many philosophers have attempted to clearly articulate the relation between metaphysics and physics, pursuing approaches that either reduce drastically the scope of metaphysical work, or rescue some autonomy and independence.

Suggested References

Morganti, M. and Takho, T. 2017. “Moderately naturalistic metaphysics”. *Synthese.* 194, pages 2557–2580

Ladyman, J. and Ross, D. 2007. *Everything must go.* Oxford: Oxford University Press. (Introduction, Ch. 1)

Esfeld, M. 2018."Metaphysics of science as naturalized metaphysics", in Anouk Barberousse, Denis Bonnay and Mikaël Cozic (eds.). *The philosophy of science. A companion.* Oxford: Oxford University Press, pp. 142–170.

Melnyk, A. 2013. "Can Metaphysics Be Naturalized? And If So, How?" In Don Ross, James Ladyman Harold Kincaid (eds.), *Scientific Metaphysics.* Oxford University Press. pp. 79-95.

7.2. Paradigmatic Shifts in Physics

The history of science is punctuated by paradigmatic shifts—profound transformations in the the foundational framework of its theories. A paradigmatic shift does not merely involve incremental progress; it represents a fundamental reorientation of the scientific landscape, often challenging established norms and assumptions. Such shifts are crucial for the advancement of knowledge. This project explores the nature of paradigmatic shifts in theoretical physics, illustrating how they have advanced the discipline. In this project, the students can study the nature of paradigmatic shifts within theories of physics and explore their intersection with questions regarding ontology. This exploration includes examining how the ontological commitments and descriptions of reality may or may not change from one paradigm to the another. The students can study paradigmatic shifts in some specific physical theories, including the transition from classical mechanics to quantum mechanics and the shift from Newtonian gravity to Einstein's theory of general relativity.

Suggested References

Kuhn, T. S. 1962. *"The Structure of Scientific Revolutions."* University of Chicago Press. (Chapters 6-8)

Weinberg, S. 1992. *"Dreams of a Final Theory."* Pantheon Books. (Chapter 2)

Einstein, A. 1916. *"The Foundation of the General Theory of Relativity."* Annalen der Physik, 354(7), 769-822.

Heisenberg, W. 1949. *"The Physical Principles of the Quantum Theory."* University of Chicago Press.

7.3. 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

7.4. Symmetries and Ontology

Ontology is the study of what there is and what is fundamental. In recent years, philosophers of physics and metaphysicians of science have drawn their attention to symmetries as guides to ontology. For instance, what is the nature of space and time, what are the natural properties of the natural world, or what are its fundamental structures are the sort of questions that philosophers have lately investigated by looking at physical symmetries. Though many have endorsed this strategy (endorsing some form of symmetry realism), others have resisted (endorsing some form of symmetry epistemicism or pragmatism). The question remains: may symmetries (v.g., space-time symmetries, local gauge symmetries, permutation symmetries, among others) be guides to ontology?

Suggested References

Melnyk, A. 2013. "Can Metaphysics Be Naturalized? And If So, How?" In Don Ross, James Ladyman Harold Kincaid (eds.), *Scientific Metaphysics.* Oxford University Press. pp. 79-95.

Baker, D. (2010). "Symmetry and the metaphysics of physics". *Philosophy Compass* 5: 1157-1166.

Brading, K. and E. Castellani. (2007). "Symmetries and Invariances in Classical Physics". *Handbook of the Philosophy of Science, Philosophy of Physics, Part B.* Eds.

J. Butterfield and J. Earman. The Netherlands: Elsevier, 1331–1367.

Dasgupta, S. (2016). "Symmetry as an epistemic notion (twice over)". *British Journal for Philosophy of Science*, 67: 837-878.

Martin, C. (2002). "Gauge principle, gauge arguments and the logic of nature". *Philosophy of Science*, 69: S221-234.

McKenzie, K. (2014). "On the fundamentality of symmetries". *Philosophy of Science*, 81: 1090-1102.

Wigner, E. (1963). "Events, laws of nature, and invariance principles". *Nobel Lecture*, December 12.

8. Philosophy of Space and Time

8.1. 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) founded the contemporary debate on the nature of space time in philosophy of physics and 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 held among substances (e.g., particles), but there does not exist nothing like space and time on their own. *Substantivalism* holds that space and time are irreducible and they exist on a par with matter. *Super-substantivalism* holds that there is no matter, but only space and time. Though many physical theories seem to support substantivalism, in recent years new relational formulations of classical mechanics, general relativity and quantum mechanics have been carried out, 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.

8.2. The Direction of Time

Philosophers and physicists have been discussing about the nature of the direction of time for over a century. In philosophy of physics, three approaches can be distinguished: primitivism, reductionism, and eliminativism. *Primitivists* believe that the direction of time is somehow part of the fundamental furniture of the natural world, and thereby, is irreducible (e.g., it is an intrinsic property of the spatial-temporal structure). *Reductionists* believe that the direction of time is a second-order property of the natural world, which can be reduced to non-temporal asymmetries (e.g., the increase of entropy plus a low-entropy initial condition). *Eliminativists* believe that the direction of time is unreal and an illusion, despite the fact the time seems to be directed. Though many physical theories seem to give support to reductionism, or even eliminativism, primitivism cannot be discarded 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.

8.3. Time Reversal and Time-Reversal Invariance

Many philosophers and physicists would accept the following inference: if the laws of nature are time-reversal invariant, then there is no direction of time (at least at the fundamental level). Since (most) laws of nature are time-reversal invariant, it follows that there is no direction of time, as long as physics is concerned. Yet, is this true? There has been some debate about it, mainly along two lines. First, some have argued that it is not true that laws of nature are time-reversal invariant, since some decays in weak interactions violate CP, and therefore, T (time-reversal invariance). In addition, some non-fundamental interactions are non-time-reversal invariant. Second, others have claimed the meaning, relevance, and canonical implementations of time-reversal invariance can be put into question, which would downplay the conclusion in the inference. The philosophical analysis of such a simple and widely accepted inference leads us to consider the relation between symmetries and ontology, the role of symmetries in physical theories, the relevance of experimental results, and the nature of time reversal in classical electromagnetism and quantum theories.

Suggested References

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

Callender, C. 2000. "Is time 'handed' in a quantum world?" *Proceedings of the Aristotelian Society*, 100: 247-269.

Lopez, C. 2021 "Three faces of time-reversal invariance". *European Journal for Philosophy of Science*, 11 :51.

Lopez, C. 2021. "The physics and philosophy of time-reversal invariance". *Synthese*,199, pages 14267–14292

North, J. 2008. "Two views on time reversal". *Philosophy of Science*, 75, 201–223.

Peterson, D. 2015. “Prospect for a new account of time reversal”. *Studies in History and Philosophy of Modern Physics*, 49: 42-56.

Roberts, B. 2017. “Three myths about time reversal invariance”. *Philosophy of Science*, 84, 2: 315-334.

8.4. 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.

9. Philosophy of Quantum Physics

9.1. 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.

9.2. 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

9.3. 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

10. Foundations of Modern physics

10.1. 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

der, W.B.L. van (2007) *Sources of Quantum Mechanics.* Mineola, NY: Dover.

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

10.2. 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

11. 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.

11.1. 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

11.2. The Success of Mathematics in the Natural Sciences

In a now famous essay, Nobel-prize winning physicists Eugene Wigner wondered about the "unreasonable effectiveness of mathematics in the natural sciences." This started a philosophical debate that persists to this day. Indeed, mathematics is not only the "language" of physics, it also plays a crucial role special sciences from chemistry to biology to social and economic sciences. How can this successes be explained, given that mathematics seems to be about 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

11.3. 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.

12. 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.12.2)? (2) Does the human mind work the way we know computers do (Sec.12.3) ? Although the two inquiries interrelate, it is wise to keep them apart for present purposes.

12.1. 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". *https://plato.stanford.edu/entries/artificial-intelligence/*

Internet Encyclopedia of Philosophy: "Artificial Intelligence". *https://iep.utm.edu/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). *https://www.nature.com/articles/s41599-020-0494-4*

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

Huge collection of philosophical papers on the question: *https://philpapers.org/browse/can-machines-think*

12.2. 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.

Suggested References

Chalmers, David J., Could a Large Language Model be Conscious?

Manzotti, Riccardo and Owcarz, Gregory. 2020. “The Ontological Impossibility of Digital Consciousness”. *Mind & Matter* Vo. 18(1), pp. 61-72

Jaegwon Kim. 1998. *Mind in a physical world: An essay on the mind-body problem and mental causation*. MIT press (physicalism)

David Lewis. 1972. “Psychophysical and Theoretical Identifications.” *Australasian Journal of Philosophy* 50(3): 249–258 (physicalism).

David Chalmers. 1996. *The Conscious Mind*. New York: Oxford University Press (esp. chs. 1, 3.1–2, 4.1–2, 7). (property dualism).

William Hasker. 1999. *The Emergent Self*. Ithaca: Cornell University Press. Chapter 2 (anti-physicalism and property dualism).

Charles Taliaferro. 2018. “Substance Dualism: A Defense.” In: *The Blackwell Companion to Substance Dualism*, ed. Loose, Menuge and Moreland. Wiley Blackwell.

12.3. 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).

Suggested References

Putnam, Hilary. 1960. "Minds and Machines." (pro computationalism)

Lucas, John R. 1961. "Minds, Machines and Godel." *Philosophy* 36 (137): 112–27.
Rejoinders by John Lucas to critics of his argument: https://philpapers.org/s/john%20lucas%202003

Searle, John R. 1980. "Minds, Brains, and Programs." *Behavioral and Brain Sciences* 3 (3): 417–24. https://doi.org/10.1017/S0140525X00005756.

Chalmers, David J. 2011. "A Computational Foundation for the Study of Cognition." *Journal of Cognitive Science* 12 (4): 325–59.

Feser, Edward. 2013. "Kripke, Ross, and the Immaterial Aspects of Thought." *American Catholic Philosophical Quarterly* 87 (1): 1–32.

Huge collection of philosophical papers on the question: https://philpapers.org/browse/godelian-arguments-against-ai

13. Free Will and Science

13.1. Is Free Will compatible with Laws of Nature?

It is an integral part of our self-image as human beings that we have free will, i.e., that we are the originators of our actions and can choose between alternative courses of action. The rise of modern science, however, gave rise to a tension: if the laws of nature hold strictly, then what room is there for free will, if any? Or does the purported problem suffer from a misconception of what laws of nature are? This project investigates these questions.

Suggested References

Alin C. Cucu and Brian Pitts. 2019. “How Dualists Should (Not) Respond to the Objection from Energy Conservation.” *Mind and Matter* 17(1): 95–121

Angus Menuge. 2009. “Is Downward Causation Possible?: How the Mind Can Make a Physical Difference.” *Philosophia Christi* 11(1): 93–110.

Michael Esfeld. 2020. *Science and Human Freedom.* Springer

Pieter Thyssen and Sylvia Wenmackers. 2020. “Degrees of freedom.” *Synthese*: 1-29

Jeffrey Koperski. 2017. “Breaking Laws of Nature.” *Philosophia Christi* 19(1) : 83-101

Richard Swinburne. 2013. *Mind, Brain, and Free Will.* Oxford: Oxford University Press. Chapter 5

13.2. Free Will and Neuroscience

In the 1980s, Benjamin Libet carried out his seminal experiments that explored the temporal relationship between a person’s intention to act and the onset of pertinent brain activity. His findings – and those of subsequent experiments in the same vein – are often taken to show that it is not us, but our brain, that acts. The question is whether this conclusion is justified, or more generally, how these results from neuroscience should be interpreted in regard to what they tell us about free will.

Suggested References

Alfred R. Mele. 2014. *Why Science Hasn’t Disproved Free Will.* Oxford, New York: Oxford University Press

Richard Swinburne. 2013. *Mind, Brain, and Free Will.* Oxford: Oxford University Press. Chap. 4.3

Joshua Shepherd. 2017. “Neuroscientific Threaths to Free Will.” In: Meghan Griffith, Kevin Timpe, & Neil Levy (eds.). *The Routledge Companion to Free Will.* Routledge

Michael Gazzaniga. 2012. *Who’s in Charge?: Free Will and the Science of the Brain.* Hachette UK

Mark Hallett. 2007. ”Volitional Control of Movement: The Physiology of Free Will.” *Clinical Neurophysiology* 118: 1179–92