SHS Course

Philosophical Perspectives on the Exact Sciences I+II

Prof. Michael Esfeld*

Academic Year 2021–22
Manual Version: August 10, 2021

The goal of this master programme is to acquire the skills necessary to address philosophical questions that aris 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 interst – in coordination with a supervisor – but are encouraged to work on a philosophical project related to their field of study at the EPFL.

*. ✉ Michael.Esfeld@unil.ch

Contents

Part I. Organization

1. Supervisors

Teaching assistant for this course is Dr. Dustin Lazarovici[1]. He stands at your disposal for any questions regarding the course and will supervise most of the projects. Also involved in the supervision of particular projects is

– Alin Cucu (Alin.Cucu@unil.ch)

One of them will be assigned as a supervisor to your group and assist you in preparing the essay.

2. The Program

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 and History of Classical Physics,

– Philosophy of Relativistic Physics,

– Philosophy and History of Quantum Mechanics,

– 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 Dustin Lazarovici or your respective supervisor.

1. ✉ Dustin.Lazarovici@unil.ch

3. What You Are Expected to Do

1. Follow the introductory lectures starting on 22 September 2021.
2. Find a group and a project by 27 October 2021.
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 2022.
6. Submit final version of the essay, after receiving feedback on the first draft, by 1 June 2022.

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. And 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, French, or 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 your essay plan and presentation, including the discussion. You don't need 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 (this would exceed expectations for the course) 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 on your native tongue, but clear and precise formulations matter in philosophical writing. You may use the help of an external proofreader or software to improve the language of your essay.

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 succintly summarize the main contents and results of your paper.

The main text consist 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 part. For philosophical papers, it is considered good practice to present different opposing positions and discuss the respective arguments and counter-arguments. However, you don't have to 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 philosophy of physics, mathematics, or a special science.

Length

There is *no firm word limit or minimal word count.* The *suggested* word count depends on the number of authors contributing to your essay:

- 1 author: 4000–5000 words,
- 2 authors: 5000–6000 words,
- 3 authors: 6000–7500 words.

The word count includes everything in the main text, headings, quotes and footnotes, but not the abstract and bibliography. 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. We will provide more guidelines on proper citation in the last lecture of the course.

Grading

We will grade your essay based on the following criteria:

- Did you demonstrate a good understanding of your research topic and the related philosophical debates?
- 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?

Submission

Please send a complete version of your essay to your supervisor by **1 May 2022**. We only accept PDF or Word documents. Please use the official cover page that you can download from the website of the SHS program or the moodle site of the seminar. 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 2022**.

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 let your supervisor know in time if you intend to do a one-term project.

4. Schedule

Autumn Term '21

The autumn term is divided into three parts:

1. Lectures

Location: Room INR 219.

The lectures will be held in class, if circumastances permit. Please pay attantion to possible public health restrictions.

Wed. 22 September
16h15-17h30: Introduction to the Program. (Prof. Esfeld)
17h45-18h45: Natural Philosophy: Newton on Physics and Philosophy. (Prof. Esfeld)

29 September
16h15-17h30: Philosophy of Space and Time: Leibniz vs. Newton (Esfeld; Lazarovici)
17h45-18h45: What Is a Law of Nature? Theory and Ontology. (Esfeld; Lazarovici)

6 October
16h15-17h30: Quantum Physics: Non-Locality and the Measurement Problem. (Esfeld)
17h45-18h45: The Ontology of Quantum Physics. (Prof. Esfeld)

13 October
16h15-17h30: Aritifical Intelligence. (Dr. Lazarovici)
17h45-18h45: Mind and Free Will. (Prof. Esfeld)

20 October
16h15-17h30: Philosophy of Mathematics. (Dr. Lazarovici)

17h45-18h45: How to Write an Essay. (Dr. Lazarovici)

2. Preparation of the Essay Plan

- No lectures until the presentations.
- Definite fixing of the groups and essay topics by **Wednesday, 27 October**.
- One required meeting with your supervisor (in person or via Zoom), further meetings upon request. Meetings can be scheduled via moodle.
- 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

- 1 December,
- 8 December,
- 15 December,
- 22 December,

The exact presentation schedule will be posted on moodle. There you will find the date and time assigned to your group.

Spring Term '22

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 2022**. Your supervisor will give you feedback. If your essay needs improvement, you can submit a revised and final version until **1 June 2022**.

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

Open peer-reviewed sources on the internet are:

- The Stanford Encyclopedia of Philosophy (SEP).
- The Internet Encyclopedia of Philosophy (IEP).
- Scholarpedia.

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 topic from physics.

We strongly recommend not to use other online sources unless you run them by 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 vary 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 stated in the book or this manual, you can formulate your own research topic in consultation with your supervisor.

7. Proposed Research Projects

7.1. 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

Online Lectures

- How Theory Meets Data by Tim Maudlin.
- What Theories Qualify as Quantum Theories without Observers? by Tim Maudlin.
- A Physicist Looks at Idealism and Relativism by Jean Bricmont.

7.2. Newton vs. Leibniz on Space, Time, and Motion

What is the nature of time and space? Are space and time absolute? Does space exist independently of the objects populating it, or does it reduce to spatial relations between physical entities? This, in brief, was the subject of the epic debate between Isaac Newton (1643–1727) and Gottfried Wilhelm Leibniz (1646–1717). The question remains highly relevant even today and must be consistently reevaluated on the basis of our best physical theories.

Suggested References

Nick Huggett, ed. 1999. *Space from Zeno to Einstein.* Cambridge, MA: MIT Press. Chapters 7–8

Tim Maudlin. 2012. *Philosophy of Physics: Space and Time.* Princeton, NJ: Princeton University Press. Chapters 1–2

7.3. What is Light?

The existence of “light” is in some sense obvious. We can see it, we can manipulate it, we can do experiments with it. However, if we look at our physical theories, the role of “light” or, more generally, the electromagnetic field is really to mediate interactions between particles. So what exactly is the electromagnetic field and why should we believe in its “reality”? In fact, there exists a formulation of classical electrodynamics (Wheeler-Feynman electrodynamics) in terms of direct particle interactions that involves no fields at all. The main motivation for considering such a theory is that the concept of fields as mediators of particle interactions is problematic, leading in particular to self-interaction singularities, where the strength of the field, acting back on a point particle, becomes infinite. Investigating the status of the electromagnetic field is thus an interesting and important problem from both a physical and a philosophical point of view.

Suggested References

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

Dustin Lazarovici. 2018. "Against Fields." *European Journal for Philosophy of Science* 8:145–170. https://doi.org/10.1007/s13194-017-0179-z

Brent Mundy. 1989. "Distant Action in Classical Electromagnetic Theory." *The British Journal for the Philosophy of Science* 40 (1): 39–68

John Archibald Wheeler and Richard Phillips Feynman. 1945. "Interaction with the Absorber as the Mechanism of Radiation." *Reviews of Modern Physics* 17 (2–3): 157–81

7.4. Entropy and the Arrow of Time

Why is there an arrow of time in our universe which seems to be guided, on the fundamental level, by time-symmetric microscopic laws? The most promising answer was given by Ludwig Boltzmann who laid the foundations of statistical mechanics and provided a microscopic explanation of the second law of thermodynamics, establishing irreversible macroscopic behavior characterized by an increase of entropy.

Understanding Boltzmann's insights is a subtle but important issues. Moreover, there are at least two difficult and controversial debates surrounding the thermodynamic arrow of time. For one, the Boltzmannian account of the thermodynamic arrow requires the assumption that our universe started in an extremely unlikely, low-entropy state. What is the status of this "Past Hypothesis"? Is it a law of nature? Does it have to be explained? Finally, the question remains whether the thermodynamic asymmetry is sufficient to explain the difference between "past" and "future" or whether there exists a primitive directionality or "flow" of time.

Suggested References

David Z. Albert. 2009. *Time and Chance.* Harvard University Press. ISBN: 978-0-674-02013-9

J. Bricmont. 1995. "Science of Chaos or Chaos in Science?" *Annals of the New York Academy of Sciences* 775 (1): 131–175. https://doi.org/10.1111/j.1749-6632.1996.tb23135.x

Sean Carroll. 2010. *From Eternity to Here.* New York: Dutton

Sheldon Goldstein. 2001. “Boltzmann’s Approach to Statistical Mechanics.” In *Chance in Physics: Foundations and Perspectives,* edited by J. Bricmont et al., 39–54. Heidelberg: Springer

Dustin Lazarovici and Paula Reichert. 2015. “Typicality, Irreversibility and the Status of Macroscopic Laws.” *Erkenntnis* 80 (4): 689–716

Roger Penrose. 1999. *The Emperor’s New Mind: Concerning Computers, Minds, and the Laws of Physics.* New Edition. OUP Oxford. ISBN: 978-0-19-286198-6. Chapter 7

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.

7.5. The Twin Paradox

One of two twins leaves in a space shuttle that travels close to the speed of light. When he returns, he finds that his twin brother has aged much more than he did. This, in short, is the infamous “twin paradox” that illustrates one of the most counterintuitive features of Einstein’s theory of special relativity. While many false explanations are presented in physics textbooks, a proper analysis of the phenomenon yields deep insights into the nature of relativistic spacetime.

Suggested References

Harvey R. Brown. 2007. *Physical Relativity: Space-Time Structure from a Dynamical Perspective.* Oxford, New York: Oxford University Press. ISBN: 978-0-19-923292-5

Robert Geroch. 1978. *General Relativity from A to B.* Chicago: The University of Chicago Press. Chaps. 1, 5, and 6

Tim Maudlin. 2012. *Philosophy of Physics: Space and Time.* Princeton, NJ: Princeton University Press. Chapter 4

7.6. Space-Time in General Relativity

Einstein’s theory of general relativity is our current best theory of spacetime. Geroch (1978, Chap. 7 and 8) and Maudlin (2012) are good conceptual introductions 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.

7.7. Is Time Travel Possible?

Some solutions of General Relativity contain "closed time-like curves" that would allow for time travel. But is time travel really possible in our actual universe? Arntzenius and Maudlin (2002) discuss this issue. Their article is also an entry in the Stanford Encyclopedia of Philosophy.

Suggested References

Frank Arntzenius and Tim Maudlin. 2002. "Time Travel and Modern Physics." In *Time, Reality & Experience,* edited by Craig Callender, 169–200. Cambridge, UK: Cambridge University Press

David Deutsch. 1991. "Quantum Mechanics near Closed Timelike Lines." *Physical Review D* 44 (10): 3197–3217. https://doi.org/10.1103/PhysRevD.44.3197

David Deutsch and Michael Lockwood. 2016. "The Quantum Physics of Time Travel." In *Science Fiction and Philosophy,* edited by Susan Schneider, 370–383. John Wiley & Sons, Inc. ISBN: 978-1-118-92259-0. https://doi.org/10.1002/9781118922590.ch27

7.8. 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. The nonlocality of nonlocality also raises questions about the compatibility with Einsteinian relativity that are the subject of ongoing investigations.

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.

7.9. 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

7.10. 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

7.11. Bohmian Mechanics

Bohmian Mechanics grounds the predictions of textbook quantum mechanics in a particle ontology and a nonlocal law of motion in which the quantum wave function enters. This theory has no measurement problem because a physical system has a well-defined spatial configuration determined by the position of its constituting particles. The usual quantum formalism, including Born’s rule and operators as “observables”, then arises from a statistical analysis of the theory. Although Bohmian Mechanics provides a clear and simple solution to the problems of orthodox quantum mechanics, it is still a very controversial theory.

Suggested References

Jean Bricmont. 2016. *Making Sense of Quantum Mechanics.* Switzerland: Springer International Publishing

Detlef Dürr and Stefan Teufel. 2009. *Bohmian Mechanics: The Physics and Mathematics of Quantum Theory.* Berlin: Springer

Oliver Passon. 2006. "What You Always Wanted to Know about Bohmian Mechanics but Were Afraid to Ask." arXiv: quant-ph/0611032.

Online Lectures

- A video series on Bohmian mechanics.
- Bohmian Mechanics: Speakable Quantum Physics by Detlef Dürr.
- Bohmian Mechanics by Stefan Teufel.

7.12. The Many–Worlds Theory

The Many–Worlds Interpretation is the most radical reaction to the measurement problem. It accepts that macroscopic superpositions exist and that all states in such a superposition are equally real. This means, in particular, that after any quantum measurement, all possible outcomes are realized in different "worlds". Conceptually, this theory is interesting because it tries to develop an objection description of physical reality from the wave function/ quantum state and its unitary evolution only.

Suggested References

Hugh Everett. 1973. "The Theory of the Universal Wave Function." *The Many-Worlds Interpretation of Quantum Mechanics,* 3–140

Tim Maudlin. 2014. "Critical Study—David Wallace, The Emergent Multiverse: Quantum Theory According to the Everett Interpretation." *Noûs* 48 (4): 794–808

David Wallace. 2012. *The Emergent Multiverse: Quantum Theory According to the Everett Interpretation.* Oxford: Oxford University Press

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

Online Lectures

- The Emergent Multiverse I: The Plurality of Worlds by David Wallace.
- The Emergent Multiverse II: The Probability Puzzle by David Wallace.

7.13. 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

7.14. 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

7.15. Could Machines Think?

Computationalism is a position in the philosophy of mind. It holds that the mind is essentially a computational system. This implies, in particular, that any machine, running a sufficiently complex algorithm that implements the functional tasks of the human brain, would be conscious. On the other hand, several authors have argued against this view. With the rapid advances in quantum science an the rise of so-called "artificial intelligence", this debate seems more relevant than ever.

Suggested References

David J. Chalmers. 2011. "A Computational Foundation for the Study of Cognition." *Journal of Cognitive Science* 12 (4): 323–357

Tim Maudlin. 1989. "Computation and Consciousness." *The Journal of Philosophy* 86 (8): 407–432. https://doi.org/10.2307/2026650

Roger Penrose. 1999. *The Emperor's New Mind: Concerning Computers, Minds, and the Laws of Physics.* New Edition. OUP Oxford. ISBN: 978-0-19-286198-6

John R. Searle. 1980. "Minds, Brains and Programs." *Behavioral and Brain Sciences* 3 (3): 417–57

Alan M. Turing. 1950. "Computing Machinery and Intelligence." *Mind* 59:433–60

7.16. Artificial Intelligence and its Consequences

With the rise of artificial intelligence, debates about the promises and risks of intelligent machines are more relevant than ever. Is an "intelligence explosion" inevitable? Will machines replace humans as the most powerful "species" on earth and if so, what does it mean for humanity? Should we fear or embrace superintelligent AI? And how could we control it? These are among the questions that this project can explore.

Suggested References

Margaret A. Boden, ed. 1990. *The Philosophy of Artificial Intelligence.* Oxford Readings in Philosophy. Oxford, New York: Oxford University Press

Nick Bostrom. 2014. *Superintelligence: Paths, Dangers, Strategies.* Oxford, New York: Oxford University Press. ISBN: 978-0-19-967811-2

Stuart Russell. 2020. *Humanly Compatible: Artificial Intelligence and the Problem of Control.* Viking/Penguin Random House

Online Lectures

Don't Trust the Promise of Artificial Intelligence. Debate by Intelligence Squared.

7.17. 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

7.18. 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

7.19. Can Science Explain Consciousness?

Physicalists believe that everything that exists is physical, which includes consciousness. Thus, physicalists must offer an explanation of how conscious states can be analyzed wholly in terms of physical states. The wider group of naturalists believe that even if consciousness is non-physical, its generation must be scientifically explainable. Which one of these views, or whether a non-naturalistic take on consciousness, has the upper hand, is the question to be addressed in this project.

Suggested References

David Chalmers. 1996. *The Conscious Mind.* New York: Oxford University Press

David Lewis. 1972. "Psychophysical and theoretical identifications." *Australasian Journal of Philosophy* 50(3): 249-258

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

William Hasker. 1999. *The Emergent Self.* Ithaca: Cornell University Press. Chap. 1-2

David Papineau. 2000. "The Rise of Physicalism." In: M. W. F. Stone and J. Wolff (eds.) *The Proper Ambition of Science*New York: Routledge. 174–208