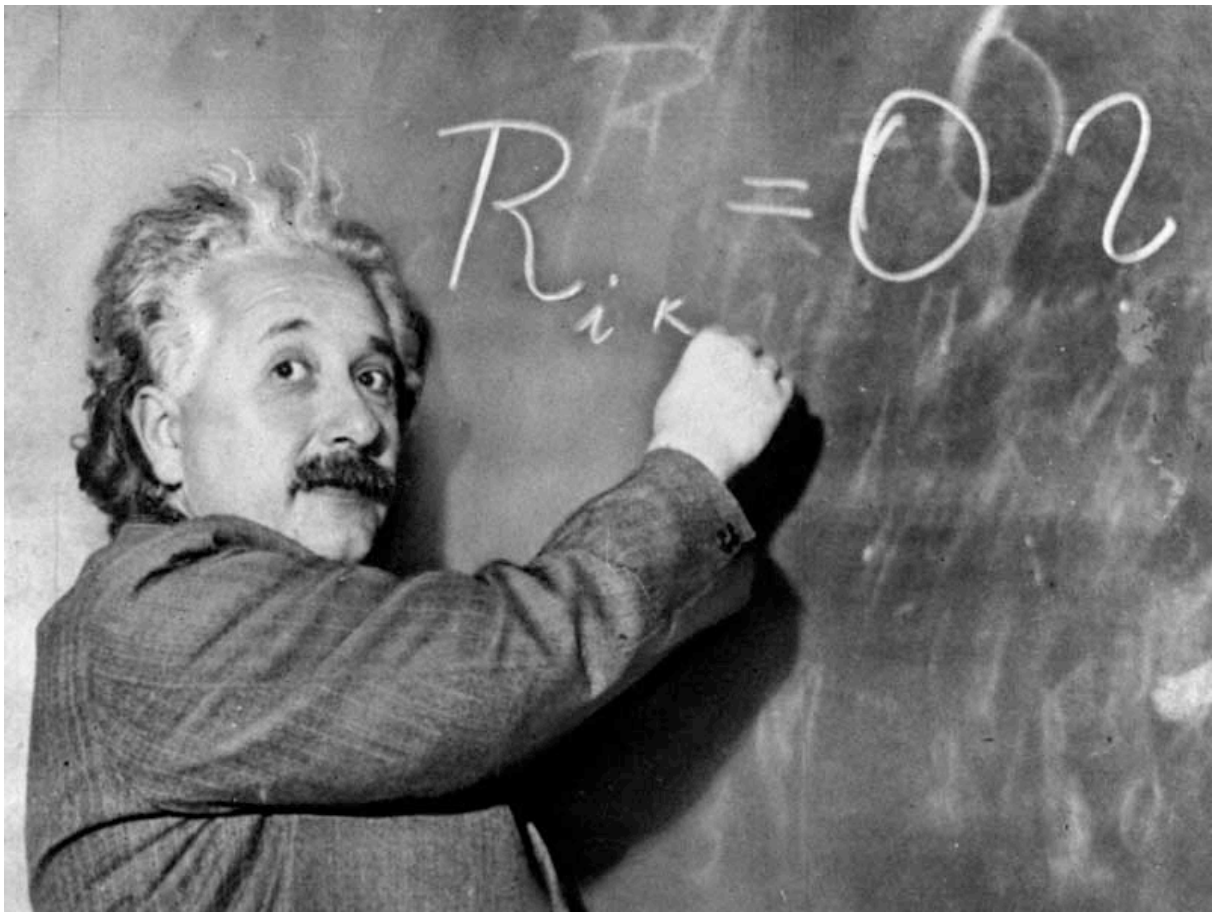
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Academic year 2011-12

Philosophical perspectives on the exact sciences and their history

Master projects

Michael Esfeld
with Matthias Egg and Tim Raez



ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Academic year 2011-12

Philosophical perspectives on the exact sciences and their history SHS projects

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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. How did the visions of space and time change from Galileo via Newton to Einstein? What is matter following the revolution introduced by quantum physics? What is a law of nature? Do mathematical objects really exist? What is the relationship between the microphysical world and the world of common sense? These questions, among many others, will be tackled in the philosophical reflection on the exact sciences and their history that this master module offers. Reflecting on these issues provides intellectual tools for a better understanding of today's science and technologies. After an introductory teaching, the students work in small groups of 1 to 3 students on a particular project and present their intermediate results to the whole group. Students are free to choose the project that interests them most, but we encourage them to work on a project that is about philosophical issues raised in connection with their main branch at EPFL.

The programme

The goal of the master programme is to acquire the skills necessary to address the philosophical questions that are raised by the natural sciences and their history. You will work in small groups of 1 to 3 students on a particular project. **We encourage you to work on a project according to your interests. You are welcome to choose a project that is about philosophical issues raised in connection with your main branch at EPFL.** Our suggestions for projects are contained in this booklet, grouped into projects in relation to physics, projetcs related to mathematics and projects about general topics in philosophy of science. If you wish to work on a topic that is not indicated in this booklet, please contact us.

What you are expected to do

Follow the introductory teaching, submit an essay plan by 23 November 2011, present your plan to the whole group in December and work out the essay by 30 April 2012. You can write the essay in English, French or German. The presentations, however, should be in English.
The essay should contain three main parts:

a) an introduction in which you spell out your research question, tell the reader why this question is interesting and put it into a general framework;
b) a main part in which you develop your argument, give examples, discuss possible objections, establish, if appropriate, a link with research topics in the main branch that you study at EPFL, etc. Be clear and concise. Do not mention too many details, but make sure that your essay has a clear structure. Do not merely repeat or recount what is in the texts that you have read, but provide an intelligible account of their argumentative structure;
c) a conclusion that sums up your results and that contains a personal evaluation.

An essay written by one student should be about 15 pages, an essay by a group of two students about 20 pages, and a group of three students about 25 pages. When you quote from the literature, make sure that you always indicate the source. References should be sufficiently precise to enable your reader to find the relevant passage in the original work. Never copy or rephrase texts that you have found in the literature or on the internet without clearly indicating the source (plagiarism).

General references

guidelines for writing an essay in philosophy:
http://www.jimpryor.net/teaching/guidelines/writing.html

introductory book to the philosophy of science in French:
Esfeld, Michael (2009): *Philosophie des sciences. Une introduction*. Lausanne: Presses polytechniques et universitaires romandes. Deuxième édition.

introductory book to the philosophy of science in English:
Ladyman, James (2002): *Understanding philosophy of science*. London: Routledge.

philosopohy of science dictionary in French:
Nadeau, Robert (1999): *Vocabulaire technique et analytique de l'épistémologie*. Paris: Presses universitaires de France.

philosopohy of science dictionary in English:
Newton-Smith, William H. (ed.) (2000): *A companion to the philosophy of science*. Oxford: Blackwell.

Psillos, Stathis & Curd, Martin (eds.) (2008): *The Routledge companion to philosophy of science*. London: Routledge.

history and philosophy of science dictionary in French:
Lecourt, Dominique (dir.) (1999): *Dictionnaire d'histoire et philosophie des sciences*. Paris: PUF.

history of science dictionary in English:
Hessenbruch, Arne (ed.) (2000): *Reader's guide to the history of science*. London: Fitzroy Dearborn.

internet dictionary in philosophy:
Stanford Encyclopedia of Philosophy: http://plato.stanford.edu

The Internet Encyclopedia of Philosophy: http://www.iep.utm.edu/

Schedule

Autumn term:
Wed 21 Sept.:
16h15-17h30 Michael Esfeld: Introduction to the programme
17h45-18h45 Matthias Egg: How to write an essay
Wed 28 Sept.:
16h15-17h30 Matthias Egg: Scientific realism
17h45-18h45 Matthias Egg: Causal explanations
Wed 5 Oct.:
16h15-17h30 Michael Esfeld: Philosophy of space and time: the classical positions
17h45-18h45 Michael Esfeld: Philosophy of space and time: the contemporary debate
Wed 12 Oct.:
16h15-17h30 Michael Esfeld: The quantum measurement problem
17h45-18h45 Matthias Egg: Philosophical issues of quantum field theory
Wed 19 Oct.:
16h15-17h30 Tim Raez: Philosophy of mathematics
17h45-18h45 Definite fixing of the groups & essay subjects
Work on essay plan, one meeting with supervising assistant; submit essay plan to supervising assistant by 23 Nov. (or at least one week before your presentation).
Wed 30 Nov., Wed 7 Dec., Wed 14 Dec., Wed 21 Dec. 16h15-18h45:
Presentations of essay plans: 15 minutes presentation (power point), 15 minutes discussion.

Spring term:
Write the essay. At least two meetings with supervising assistant: one in February to discuss intermediate progress, one in May to discuss results.

Suggestions of projects

Philosophy and history of physics (supervising assistant Matthias Egg)

1) Newton on space, time and motion

Essential bibliography:

Dainton, Barry (2001): *Time and Space*. Chelsam: Acumen. Chapters 10 & 11.

Earman, John (1989): *World enough and space-time. Absolute versus relational theories of space and time*. Cambridge (Massachusetts) : MIT Press. Chapters 1, 4 & 6.

Huggett, Nick & Hoefer, Carl (2006): "Absolute and relational theories of space and motion". In: E. N. Zalta (ed.): *The Standford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/spacetime-theories.

Rynasiewicz, Robert (2004): "Newton's views on space, time, and motion". In: E. N. Zalta (ed.): *The Standford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/newton-stm.

Belot, Gordon (1996): *Whatever is never and nowhere is not: space, time, and ontology in classical and quantum gravity*. University of Pittsburgh: PhD Thesis. Chapter 2.

Disalle, Robert (1994): "On dynamics, indiscernibility, and spacetime ontology". *The British Journal for the Philosophy of Science*, 45: 265–287.

Lam, Vincent (2008): *Space-time within general relativity: a structural realist understanding*. University of Lausanne. PhD Thesis. Chapter 2.

Main questions:

a) According to Newton, what are absolute space and absolute time?

b) Explain and evaluate Newton's argument based on the bucket experiment.

c) What are the links beween the nature of motion and the nature of space?

d) What are the main differences between (what we think was) Newton's original position and the contemporary 'susbtantivalist' position(s) with respect to space?

e) What are the main difficulties of Newton's postion?

f) What is Disalle's postion on the traditional debate about the nature of space? What are his arguments?

2) Leibniz on space, time and motion

Essential bibliography:

Dainton, Barry (2001): *Time and* Space. Chelsam: Acumen. Chapters 10 & 11.

Earman, John (1989) : *World enough and space-time. Absolute versus relational theories of space and time*. Cambridge (Massachusetts) : MIT Press. Chapters 1, 4 & 6.

Huggett, Nick & Hoefer, Carl (2006): "Absolute and relational theories of space and motion". In: E. N. Zalta (ed.): *The Standford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/spacetime-theories.

Belot, Gordon (1996): *Whatever is never and nowhere is not: space, time, and ontology in classical and quantum gravity*. University of Pittsburgh: PhD Thesis. Chapter 2.

Mcdonough, Jeff (2007): "Leibniz's philosophy of physics". In: E. N. Zalta (ed.): *The Standford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/leibniz-physics/

Lam, Vincent (2008): *Space-time within general relativity: A structural realist understanding*. University of Lausanne. PhD Thesis. Chapter 2.

Main questions:

a) Explain and evaluate Leibniz's arguments against absolute space and time.

b) What is Leibniz's conception of space, time and motion?

c) What are the main differences between (what we think was) Leibniz's original position and the contemporary 'relationalist' position(s) with respect to space?

d) What are the main difficulties of Leibniz's position?

3) Spinoza's view on space and matter

Essential bibliography:

Earman, John (1989) : *World enough and space-time. Absolute versus relational theories of space and time*. Cambridge (Massachusetts) : MIT Press. Chapters 1 & 6.

Bennett, Jonathan (1984) : *A study of Spinoza's "Ethics"*. Cambridge : Cambridge University Press. Chapter 4.

Manning, Richard (2006) : "Spinoza's physical theory". In: E. N. Zalta (ed.): *The Standford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/spinoza-physics/

Lam, Vincent (2008): *Space-time within general relativity: A structural realist understanding*. University of Lausanne. PhD Thesis. Chapter 2.

Main questions:

a) What are the main differences between Newton's and Spinoza's conceptions of space (within Bennett's interpretation)?

b) Why is, according to Spinoza, space unique and indivisble?

c) Within Bennett's interpretation, what is a body according to Spinoza? What is the problem of such understanding? What is Bennett's solution?

d) How is motion understood within this framework?

e) What is the possible relevance of such a conception of space(-time) and matter within the framework of contemporary fundamental physics?

4) Special relativity and the philosophy of time

Essential bibliography:

Savitt, Steven (2008): "Being and Becoming in Modern Physics". In: E. N. Zalta (ed.): *The Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/spacetime-bebecome/

Dainton, Barry (2001): *Time and Space*. Chelsam: Acumen. Chapters 1-6, 16 & 17.

Putnam, Hilary (1967) : "Time and physical geometry" . *Journal of Philosophy*, 64: 240-247.

Stein, Howard (1968) : "On Einstein-Minkowski space-time". *Journal of Philosophy*, 65: 5-23.

Stein, Howard (1991) : "On relativity theory and the openness of the future". *Philosophy of Science*, 58: 147-167.

Saunders, Simon (2002) : "How relativity contradicts presentism". In: C. Callender (dir.) : *Time, reality & experience*. Cambridge : Cambridge University Press. Pp. 277-292.

Dorato, Mauro (1995) : *Time and reality. Spacetime physics and the objectivity of temporal becoming*. Bologna : Cooperativa Libraria Universitaria Editrice Bologna. Chapters 1, 11, 12 & 13.

Savitt, Steven (2000): "There's no time like the present (In Minkowski Spacetime)". *Philosophy of Science*, 67: S563-S574.

Hinchliff, Mark (2000): "A defense of presentism in a relativistic setting". *Philosophy of Science*, 67: S575-S586.

Technical bibliography:

Rindler, Wolfgang (2006): *Relativity*. Oxford: Oxford University Press. 2nd edition.

Main questions:

a) Define precisely the tensed and tenseless theories of time (in terms of the so-called A- and B-series) and of existence (presentism, possibilism, eternalism). What are the (logical) relations between them?

b) What are the most obvious arguments in favour of presentism?

c) Explain the relevant fundamental difference between Newtonian and Minkowki spacetimes.

d) Explain the different parts and issues in Putnam's argument.

e) What does Putnam's assumption 'There are no privileged observers' amount to?

f) What is the core of Stein's objection?

g) Explain and evaluate how presentism can be made compatible with special relativity.

5) The structural nature of space-time within general relativity

Essential bibliography:

Earman, John & Norton, John (1987): "What price spacetime substantivalism? The hole story". *British Journal for the Philosophy of Science*, 38: 515–525.

Stachel, John (1993) : "The meaning of general covariance. The hole story". In: J. Earman, I. Janis, G. J. Massey & N. Rescher (eds.) : *Philosophical problems of the internal and external worlds. Essays on the philosophy of Adolf Gruenbaum*. Pittsburgh : University of Pittsburgh Press. Pp. 129-160.

Norton, John (1993): "General covariance and the foundations of general relativity: eight decades of dispute". *Reports on Progress in Physics,* 56: 791-858.

Hoefer, Carl (1996) : "The metaphysics of space-time substantivalism". *Journal of Philosophy*, 93: 5-27.

Dorato, Mauro (2000): "Substantivalism, relationism, and structural spacetime realism". *Foundations of Physics*, 30: 1605–1628.

Rovelli, Carlo (2004). *Quantum gravity*. Cambridge: Cambridge University Press. Pp. 48-78.

Rickles, Dean & French, Steven (2006): "Quantum Gravity Meets Structuralism: Interweaving Relations in the Foundations of Physics". In: D. Rickles, S. French & J. Saatsi (eds.): *The Structural Foundations of Quantum Gravity*, Oxford : Oxford University Press. Pp 1-39.

Esfeld, Michael & Lam, Vincent (2008): "Moderate structural realism about space-time". *Synthese*, 160: 27–46.

Main questions:

a) Explain what general covariance is (in the sense of invariance under active diffeomorphisms). Explain the debate about its physical meaning.

b) Define precisely substantivalism and relationalism about space-time. What are the ambiguities that sometimes plague the debate?

c) Explain the hole argument. Does it undermine all substantivalist positions?

d) What is structural realism about space-time? What are the different versions? In what sense is it a way out of the hole argument? Evaluate Dorato's claim that it is a 'tertium quid' in the debate between substantivalism and relationalism.

e) Explain and evaluate Rovelli's opposition to the existence of space-time points.

f) Explain what background independence is. What is its link with general covariance?

g) How does structural realism (at least in its moderate version) account for background independence and general covariance?

6) Bell's theorem and quantum non-separability

Essential bibliography:

Howard, Don (1989) : "Holism, separability, and the metaphysical implications of the Bell experiments". In : J. T. Cushing & E. McMullin (eds.) : *Philosophical consequences of quantum theory. Reflections on Bell's theorem*. Notre Dame : University of Notre Dame Press. Pp. 224-253.

Healey, Richard (2004): "Holism and Nonseparability in Physics". In: E. N. Zalta (ed.): *The Standford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/physics-holism/

Shimony, Abner (1993) : *Search for a naturalistic world view. Volume 2 : Natural science and metaphysics*. Cambridge : Cambridge University Press. Chapter 11.

Shimony, Abner (2004): "Bell's theorem". In: E. N. Zalta (ed.): *Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/bell-theorem.

Teller, Paul (1986) : "Relational holism and quantum mechanics". *British Journal for the Philosophy of Science*, 37: 71-81.

Esfeld, Michael (2004): "Quantum entanglement and a metaphysics of relations". *Studies in History and Philosophy of Modern Physics*, 35: 601-617.

Technical bibliography:

Laloë, Franck (2001): "Do we really understand quantum mechanics? Strange correlations, paradoxes, and theorems". *American Journal of Physics,* 69: 655-701.

Sakurai, Jun J. (1994): *Modern Quantum Mechanics*. New-York : Addison Wesley. 2nd edition.

Peres, Asher (1993): *Quantum Theory: Concepts and Methods*. Dordrecht: Kluwer.

Main questions:

a) What are the (possible) roots of the separability principle? What is its physical importance? Why, according to Einstein, do field theories carry out the separability principle "to the extreme"?

b) Explain in a precise way the quantum mechanical feature of entanglement. What are the consequences for the separability principle (under a certain interpretation)?

c) Explain the main steps of the proof of a Bell-type theorem.

d) Explain how, according to Howard for instance, the parameter independence condition and the outcome independence condition of the Bell theorem encode the locality principle and the separability condition respectively. What is the possible objection to such interpretation?

e) Explain why a violation of outcome independence does not entail any violation of the locality principle. Why would we prefer to avoid such violation? Are there other interpretations?

f) What are the possible metaphysical consequences of non-separability?

7) Identity and individuality in quantum theory

Essential bibliography:

French, Steven (2006): "Identity and Individuality in Quantum Theory". In: E. N. Zalta (ed.): *Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/qt-idind/

French, Steven & Redhead, Michael L. G. (1988): "Quantum physics and the identity of indiscernibles". *British Journal for the Philosophy of Science*, 39: 233-246.

French, Steven (1989): "Identity and individuality in classical and quantum physics". *Australasian Journal of Philosophy*, 67(4): 432–446.

Morganti, Matteo (2009): "Inherent properties and statistics with individual particles in quantum mechanics". *Studies in History and Philosophy of Modern Physics*, 40: 223-231.

French, Steven & Ladyman, James (2003) : "Remodelling structural realism : quantum physics and the metaphysics of structure". *Synthese*, 136: 31-56.

Muller, F. A. & Saundars, Simon (2008): "Discerning Fermions". *British Journal for the Philosophy of Science*, 59: 499-548.

Technical bibliography:

Sakurai, Jun J. (1994): *Modern Quantum Mechanics*. New-York : Addison Wesley. 2nd edition.

Peres, Asher (1993): *Quantum Theory: Concepts and Methods*. Dordrecht: Kluwer.

Main questions:

a) Explain and evaluate the different possibilities to ground the individuality of an object ('principles of individuality').

b) Explain in a precise way the differences between a system of classical (so-called) 'identical particles' and a system of quantum (so-called) 'identical particles'.

c) What is the received argument for considering quantum particles as 'non-individuals'?

d) Explain and evaluate the argument according to which quantum particles can still be considered as individuals.

e) Explain how precisely (standard) Leibniz's principle of the identity of the indiscernables is violated by quantum particles. How can their alleged individuality be grounded?

f) What are the possible metaphysical consequences of this alleged underdetermination?

g) Explain and evaluate Saunders' proposal to modify Leibniz's principle so that it is satisfied by fermions.

8) The measurement problem in quantum theory

Essential bibliography:

Putnam, Hilary (2005): "A philosopher looks at quantum mechanics (again)". *British Journal for the Philosophy of Science*, 56: 615-634

Albert, David Z. (1992): *Quantum Mechanics and Experience*. Cambridge MA: Harvard University Press.

Wallace, David (2008): "Philosophy of Quantum Mechanics". In: D. Rickles (ed.): *The Ashgate Companion to Contemporary Philosophy of Physics*. Aldershot: Ashgate Publishing. Pp. 16-98.

Bacciagaluppi, Guido (2004): "The role of decoherence in quantum mechanics". In: E. N. Zalta (ed.): *The Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/qm-decoherence.

Zeh, H. Dieter (1996): "The program of decoherence : ideas and concepts". In: D. Giulini, E. Joos, C. Kiefer, J. Kupsch, I.-O. Stamatescu & H. D. Zeh (eds.): *Decoherence and the appearance of a classical world in quantum theory*. Berlin: Springer. Pp. 5-34.

Vaidman, Lev (2002): "Many-Worlds Interpretation of Quantum Mechanics". In: E. N. Zalta (ed.) : *The Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/qm-manyworlds/

Barrett, Jeffrey (2003): "Everett's Relative-State Formulation of Quantum Mechanics". In: E. N. Zalta (ed.) : *The Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/qm-everett/

Wallace, David (2002): "Worlds in the Everett Interpretation". *Studies in History & Philosophy of Modern Physics*, 33: 637-661.

Goldstein, Sheldon (2009): "Bohmian Mechanics". In: E. N. Zalta (ed.) : *The Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/qm-bohm/

Ghirardi, Giancarlo (2002) : "Collapse theories". In: E. N. Zalta (ed.) : *The Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/archives/spr2002/entries/qm-collapse/

Bell, John S. (1987) : "Are there quantum jumps?". In: J. S. Bell: *Speakable and unspeakable in quantum mechanics*. Cambridge : Cambridge University Press. Pp. 201-212.

Allori, V., Goldstein, S., Tumulka, R. & Zanghi, N. (2008): "On the common structure of Bohmian mechanics and the Ghirardi-Rimini-Weber theory". *The British Journal for the Philosophy of Science*, 59(3): 353-389.

Technical bibliography:

Dickson, Michael (2007): "Non-Relativistic Quantum Mechanics". In: J. Butterfield & J. Earman (eds.): *Handbook of the Philosophy of Science. Philosophy of Physics*. Part A. Amsterdam: Elsevier. Pp 275-415; in particular Section 5 (pp. 355-381).

Busch, Paul, Lahti, Pekka J. & Mittelstaedt, Peter (1996) : The quantum theory of measurement. Berlin : Springer. Deuxième édition. 2nd edition.

Main questions:

a) Explain in a technically and conceptually precise way what the measurement problem in quantum theory is.

b) What are the two big different sets of 'solutions' to the measurement problem?

c) Explain the main points of the theory of decoherence. In what sense does it not solve the measurement problem?

d) Explain and evaluate the Everett interpretation of quantum theory (in particular the 'many worlds' interpretation). How does it solve the measurement problem? What are its main difficulties and drawbacks? How does decoherence fit into the picture?

e) Explain and evaluate the GRW theory. How does it solve the measurement problem? What are its main difficulties and drawbacks?

f) According to Allori et al. (2008), what are the two possible ontologies compatible with the GRW theory?

g) Which 'solution' to the measurement problem do you favour and for what reasons?

9) Philosophical issues in quantum field theory

Essential bibliography:

Kuhlmann, Meinard (2006): "Quantum Field Theory". In: E. N. Zalta (ed.): *The Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/quantum-field-theory/

Wallace, David (2006): "In Defence of Naiveté: The Conceptual Status of Lagrangian Quantum Field Theory". *Synthese*, 151: 33-80.

Kuhlmann, Meinard (2010) : "Why Conceptual Rigour Matters to Philosophy: on the Ontological Significance of Algebraic Quantum Field Theory". *Foundations of Physics*, 40 : 1625-1637

Teller, Paul (1995): *An Interpretive Introduction to Quantum Field Theory*. Princeton University Press.

Bain, Jonathan (2011): "Quantum Field Theory in Classical Spacetimes and Particles". *Studies in History and Philosophy of Modern Physics,* 42: 98-106.

Teller, Paul (2002): "So What *Is* the Quantum Field?", In: M. Kuhlmann, H. Lyre & A. Wayne (ed.): *Ontological Aspects of Qunatum Field Theory*. Singapore: World Scientific. Pp. 145-162.

Baker, David John (2009): "Against Field Interpretations of Quantum Field Theory". *British Journal for the Philosophy of Science,* 60: 585-609.

Fraser, Doreen (2009): "Quantum Field Theory: Underdetermination, Inconsistency, and Idealization". *Philosophy of Science,* 76: 536-567.

Technical bibliography:

't Hooft, Gerard (2007): "The Conceptual Basis of Quantum Field Theory". In: J. Butterfield & J. Earman (eds.): *Handbook of the Philosophy of Science. Philosophy of Physics*. Part A. Amsterdam: Elsevier. Pp 661-729.

Main questions:

a) Philosophical discussions on QFT can be based either on standard (Lagrangian) QFT or on Algebraic QFT. Explain and evaluate the main arguments for each of the two approaches.

b) Give a precise account of Teller's 'quanta-interpretation' of QFT. How do quanta differ from classical particles?

c) What are the main arguments against a particle-/quanta-interpretation of QFT? What is Bain's response to these arguments?

d) Can a field-interpretation be a viable alternative? What (according to Teller) is a quantum field, what is it not?

e) In what sense is QFT an example of the underdetermination of theory by empirical evidence? Evaluate Fraser's response to this problem.

10) The origin of the thermodynamic arrow of time
(project in cooperation with the Physics Section)

Essential bibliography:

Callender, Craig (2006): "Thermodynamic Asymmetry in Time". In: E. N. Zalta (ed.): *The Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/time-thermo/

Albert, David (2000): *Time and Chance*. Harvard University Press. Chapters 1-4.

Price, Huw (1996): *Time's Arrow and Archimedes' Point: New Directions for the Physics of Time*. New York: Oxford University Press. Chapter 2.

Earman, John (2006): "The 'Past Hypothesis': Not Even False". *Studies in History and Philosophy of Modern Physics*, 37: 399-430.

Callender, Craig (2004): "Measures, Explanation and the Past: Should 'Special' Initial Conditions Be Explained?" *British Journal for the Philosophy of Science*, 55: 195-217.

Callender, Craig (1999): "Reducing Thermodynamics to Statistical Mechanics: The Case of Entropy" . *Journal of Philosophy*, 96: 348-373.

Technical bibliography:

Zeh, H.Dieter (1989): *The Physical Basis of the Direction of Time*. Berlin: SpringerVerlag. Chapter 3.

Mackey, Michael C. (1992): *Time's arrow: The origins of thermodynamic behavior*. New York: Springer.

Main questions:

a) Explain in a technically and conceptually precise way what the problem of the direction of time is.

b) What is Boltzmann's famous 'H-theorem'? What are the possible objections (such as the ones of Loschmidt and Zermelo)?

c) Explain and evaluate to what extent the so-called 'Past Hypothesis' solves the problem of the direction of time.

d) What are the consequences of the second law of thermodynamics for the attempts to reduce thermodynamics to statistical physics? Do we necessarily need non time reversal invariant laws at the level of statistical physics for such theory reduction to work?

11) The notion of entropy

(project in cooperation with the Physics Section)

Essential bibliography:

Frigg, Roman & Werndl, Charlotte (forthcoming): "Entropy – a Guide to the Perplexed". Preprint available on http://philsci-archive.pitt.edu/8592/

Uffink, Jos (2001): "Bluff Your Way in the Second Law of Thermodynamics". *Studies in the History and Philosophy of Modern Physics*, 32: 305-394

Callender, Craig (1999): "Reducing Thermodynamics to Statistical Mechanics: The Case of Entropy" . *Journal of Philosophy*, 96: 348-373.

Lavenda, Bernard H. (2010): *A new perspective on thermodynamics*. Berlin: Springer.

Müller, Ingo (2007): *A history of thermodynamics. The doctrine of energy and entropy*. Berlin: Springer.

Lavis, David A. (2008): "Boltzmann, Gibbs, and the Concept of Equilibrium". *Philosophy of Science*, 75: 682-696.

Technical bibliography:

Lieb, Elliot H. & Yngvason, Jakob (1991): "The physics and mathematics of the second law of thermodynamics", *Physics Reports* 310, pp. 1-96.

Main questions:

a) Discuss the historical development of the concept of entropy.

b) What is the significance of the notion of entropy for the philosophy of physics?

c) What are the main technical and conceptual differences (and similarities) between Gibbs and Boltzmann entropies?

d) What are the problems that one encounters if one sets out to define entropy for a system out of equilibrium?

Philosophy of mathematics

(supervising assistant Tim Raez)

1) Structuralism

Essential bibliography:

http://plato.stanford.edu/entries/philosophy-mathematics/

Benacerraf, Paul, (1965): "What Numbers Could Not Be". Reprinted in: Benacerraf, Paul and Putnam, Hilary (1983): *Philosophy of Mathematics: Selected Readings*, Cambridge: Cambridge University Press, 2nd edition.

Shapiro, Stewart (2000): *Thinking about mathematics. The philosophy of mathematics*. Oxford, New York: Oxford University Press

Shapiro, Stewart (1997): *Philosophy of Mathematics. Structure and Ontology*. Oxford, New York: Oxford University Press.

Shapiro, Stewart (2008): "Identity, Indiscernibility and *ante rem S*tructuralism: The Tale of +i and -i" *Philosophia Mathematica* (III) 16, 285–309.

Räz, Tim: Ante Rem Structuralism and Set Theory. Draft.

Main questions:

a) Situate structuralism in the general context of philosophy of mathematics.

b) Characterize different formulations of structuralism as they are presented by Shapiro 1997 and argue for your favorite one.

c) Which (traditional) problems in philosophy of mathematics, as e.g. formulated by Benacerraf, are solved by (your favorite form of) structuralism?

d) How well does structuralism reflect mathematical practice? Compare different uses of 'structure' in philosophy and mathematics; give examples of matematical structures from different mathematical domains and explain the benefits of structuralism for their understanding.

e) Discuss a recent objection to structuralism: the existence of structures with non-trivial automorphism, and replies - start with Shapiro 2008

f) Reconstruct the criticism against Shapiro 2008 presented in the draft paper by Tim Räz. Discuss.

2) Mathematical explanations

Essential bibliography:

http://plato.stanford.edu/entries/mathematics-explanation/

Mancosu, Paolo (2008): "Mathematical Explanation: Why it matters", in P. Mancosu (ed.): *The Philosophy of Mathematical Practice*. Oxford: Oxford University Press.

Steiner, Mark (1978): "Mathematical Explanation", *Philosophical Studies*, 34, 135-151.

Kitcher, Philip (1989): Explanatory unification and the causal structure of the world. pages 410-505 In Kitcher, P. and Salmon, W.C., editors (1989). Scientific Explanation, volume XIII of Minnesota Studies in the Philosophy of Science, University of Minnesota Press, Minneapolis

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

Colyvan, Mark (2001): The Indispensability of Mathematics. Oxford University Press, Oxford, New York.

Main questions:

a) Distinguish explanations in pure mathematics (A) from explanations in empirical sciences using mathematics (B). Choose one type.

b) How are explanations of type (A), (B) characterized by Mancosu and others?

c) How well can cases (A) and (B) be spelled out in traditional accounts of scientific explanations, e.g. causal account, unificationist account?

d) (A): Are there explanations in pure mathematics? Do mathematicians describe themselves as giving explanations? Find examples.

e) (A):Using Steiner's account of mathematical explanations, try to work out the difference between an explanatory and a non-explanatory proof, using an example (either from the literature or your own). Use this to discuss criticisms of this account.

f) (A): Make yourself familiar with Philip Kitcher's model of explanation as unification using his 1989 paper, and the literature mentioned under point 6, explanation as unification, in the `General Topics' section below. Discuss whether unification is a good account of mathematical explanation.

g) (B): Look at specific examples from the recent literature, e.g. Baker and Colyvan. In how far is mathematics 'indispensable' for these explanations? Read up on reactions.

3) Gödel's incompleteness theorems

This project is only open to students who have taken a course in (mathematical) logic.

Essential bibliography:

Smith, Peter (2007): *An Introduction to Gödel's Theorems*. Cambridge: Cambridge University Press.

Franzén, Torkel (2005): *Gödel's Theorem: An Incomplete Guide to its Use and Abuse*. Wellesley, MA: A. K. Peters.

Main questions:

a) What is the historical background of Gödel's famous 1931 paper? Especially: What was Gödel's original goal when he started? What has Hilbert's program got to do with it?
b) Give a technically sophisticated account of the two incompleteness theorems, which should be accessible to a student who has some knowledge in mathematical logic, including completeness. Give important immediate steps leading to the results, not complete proofs. Explain the main ideas in your words. Use Smith and another, more condensed source of your choice.
c) After having gained a good understanding of the theorems and their proof: Look at the original presentation of the first theorem, Gödel 1931. Compare to a modern presentation.
d) How do the theorems affect Hilbert's program?
e) What broader philosophical consequences can be drawn from the theorems, and where do we have to be careful? Start with Franzen and discuss one particular misconception.

4) Eliminating Mathematics from Physics: Nominalism

Essential bibliography:

Field, Hartry (1980): *Science without Numbers: a defense of nominalism*. Oxford: Blackwell.

MacBride, Fraser (1999): "Listening to Fictions: a study of Feldian nominalism."
British Journal for the Philosophy of Science, (50): 431-55.

Rosen, Gideon and Burgess, John P. (1999): *A Subject With No Object. Strategies for Nominalistic Interpretation of Mathematics*. Oxford: Clarendon Press.

Entries 'Nominalism' and 'Nominalism reconsidered' in: Shapiro, Stewart (ed.) (2005): *The Oxford Handbook of Philosophy of Mathematics and Logic*. Oxford, New York: Oxford University Press.

Main questions:

a) With the help of MacBride and the other sources mentioned above: Read Field's famous 1980 essay. Give an overview of the main points.
b) Select one of the criticisms mentioned in MacBride, give a reconstruction.
c) Discuss Field's program in the light of your experiences with the use of mathematics in empirical science.

5) Cantor and the Infinite: The development of early set theory

Essential bibliography

Dauben, Joseph Warren (1979): Georg Cantor, His Mathematics and Philosophy of the Infinite. Harvard Universtiy Press, Cambridge, Mass.

Ferreiros, Jose (2007): Labyrinth of Thought. A History of Set Theory and its Role in Modern Mathematics. Birkhäuser, Basel.

Ferreiros. Jose (2011): The Early Development of Set Theory. Entry of the Stanford Encyclopedia of Philosophy, http://plato.stanford.edu/entries/settheory-early/

Main questions:

a) What was the starting point of Cantor's investigations into foundational matters of mathematics?

b) What is the distinction between potential and actual infinity?

c) What was Cantor's perspective on the infinite in the beginning of his investigations against the background of his time?

d) How did Cantor's philosophical positions especially concerning the infinite change, and how is this related to his discoveries?

e) What was the crucial factor in the discovery of set theory according to Dauben? Does Ferreiros agree?

6) Applicability of Mathematics: The Role of Mathematics in Empirical Science

Essential bibliography

Pincock, Christopher (2007): A Role for Mathematics in the Physical Sciences. Nous (41), pages 253-275

Bueno, Otavio and Mark Colyvan (2011): An Inferential Conception of the Application of Mathematics. Nous (forthc.)

Main questions:

a) According to Pincock, what principles are responsible for the puzzle of the application of mathematics to the world?

b) What is the role Pincock envisions for mathematics when applied to the world? Explain with the help of his main example. Do the same for the `Inferential conception' by Bueno and Colyvan.

c) Contrast the two accounts of the role of mathematics in application. Are the complementary, or in conflict? Use Pincock's main example to support your conclusions.

General topics in 20th/21st century philosophy of science

(supervising assistant Matthias Egg)

1) Popper's falsificationism

Essential bibliography:

Hansson, Sven Ove. 2008. Science and Pseudo-Science. In *The Stanford Encyclopedia of Philosophy (Fall 2008 Edition)*, ed E. N. Zalta. http://plato.stanford.edu/archives/fall2008/entries/pseudo-science/

Popper, Karl ([1959] 2002): *The logic of scientific discovery*. London: Routledge. Chapters 1, 4, 5, 6, 10.

Thornton, Stephen. 2009. Karl Popper. In *The Stanford Encyclopedia of Philosophy (Summer 2009 Edition)*, ed E. N. Zalta. http://plato.stanford.edu/archives/sum2009/entries/popper/

Vickers, John. 2010. The Problem of Induction. In *The Stanford Encyclopedia of Philosophy (Fall 2010 Edition)*, ed E. N. Zalta. http://plato.stanford.edu/archives/fall2010/entries/induction-problem/

Main questions:

a) What is Popper's criticism of induction?

b) How does falsificationism solve the problem of induction?

c) What does Popper's methodology of cririca rationality consist in?

d) How can this methodology be applied to the different sciences, from physics to social science?

e) How can falsificationism include a conception of progress in the history of science?

2) Kuhn's view of scientific revolutions

Essential bibliography:

Bird, Alexander. 2009. Thomas Kuhn. In *The Stanford Encyclopedia of Philosophy (Fall 2009 Edition)*, ed E. N. Zalta. http://plato.stanford.edu/archives/fall2009/entries/thomas-kuhn/

Kuhn, Thomas S. (1962): *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Oberheim, Eric, and Paul Hoyningen-Huene. 2010. The Incommensurability of Scientific Theories. In *The Stanford Encyclopedia of Philosophy (Fall 2010 Edition)*, ed E. N. Zalta. http://plato.stanford.edu/archives/fall2010/entries/incommensurability/

Main questions:

a) What is normal science?

b) How do scientific revolutions come about and why are they inevitable?

c) Is there a place for rationality in scientific revolutions?

d) What does Kuhn mean by incommensurability?

e) Can there be cognitive progress in the history of science across scientific revolutions?

3) Putnam's view of science

Essential bibliography:

Putnam, Hilary (1973): "Explanation and reference". In: G. Pearce & P. Maynard (eds.): *Conceptual change*. Dordrecht: Reidel. Pp. 199–221. Reprinted in Hilary Putnam (1975): *Mind, language and reality. Philosophical papers. Volume 2*. Cambridge: Cambridge University Press. Pp. 196–214.

Putnam, Hilary. 1975. "The Meaning of 'Meaning'". In: H. Putnam: *Mind, Language and Reality, Philosophical Papers, Volume 2*. Cambridge: Cambridge University Press, 215-271.

Main questions:

a) What is the causal theory of reference?

b) How does this theory work for theoretical terms?

c) What are the limits of the causal theory of reference?

d) How does Putnam set out to refute Kuhn's incommensurability thesis?

e) What is Putnam's view of scientific progress?

4) What is a scientific explanation? The deductive-nomological model

Essential bibliography:

Barberousse, Anouk, Kistler, Max & Ludwig, Pascal (2000): *La philosophie des sciences au XXème siècle*. Paris: Flammarion. Chapitre V.

Hempel, Carl Gustav (1965): "Aspects of scientific explanation". In: C. G. Hempel (ed.): *Aspects of scientific explanation and other essays in the philosophy of science*. New York: Free Press. Pp. 331–496.

Salmon, Wesley C. ([1989] 2006): *Four Decades of Scientific Explanation*. Reprint, Pittsburgh: University of Pittsburgh Press. Appeared previously in: Ph. Kitcher & W. C. Salmon (eds.): *Scientific Explanation*. Minneapolis: University of Minnesota Press.

Psillos, Stathis (2002) : *Causation and explanation*. Chesham: Acumen. Chapter 8.

Woodward, James. 2009. Scientific Explanation. In *The Stanford Encyclopedia of Philosophy (Fall 2009 Edition)*, ed E. N. Zalta. http://plato.stanford.edu/archives/fall2009/entries/scientific-explanation/

Main questions:

a) What is the purpose of deductive-nomological explanations?

b) What is the function of laws of nature in that model of explanation?

c) What are the central objections to the deductive-nomological model?

5) Causal explanations

Essential bibliography:

Cartwright, Nancy (1983): "Causal laws and effective strategies". In: N. Cartwright: *How the laws of physics lie*. Oxford: Oxford University Press. Pp. 21–43.

Dowe, Phil. 2008. Causal Processes. In *The Stanford Encyclopedia of Philosophy (Fall 2008 Edition)*, ed E. N. Zalta. http://plato.stanford.edu/archives/fall2008/entries/causation-process/

Salmon, Wesley C. (1998): *Causality and explanation*. Oxford: Oxford University Press. Chapters 4 and 7.

Woodward, James. 2009. Scientific Explanation. In *The Stanford Encyclopedia of Philosophy (Fall 2009 Edition)*, ed E. N. Zalta. http://plato.stanford.edu/archives/fall2009/entries/scientific-explanation/

Main questions:

a) What is Salmon's idea of a causal process and a causal interaction?

b) How do causes ground effective strategies (Cartwright)?

c) What is the relationship between causes and laws?

d) Why is it necessary to refer to causes in an explanation and how do causes explain?

6) Explanation by unification

Essential bibliography:

Friedman, Michael (1974) : "Explanation and scientific understanding". *Journal of Philosophy* 71, pp. 5-19.

Kitcher, Philip (1981) : "Explanatory unification". *Philosophy of Science* 48, pp. 507-531.

Woodward, James. 2009. Scientific Explanation. In *The Stanford Encyclopedia of Philosophy (Fall 2009 Edition)*, ed E. N. Zalta. http://plato.stanford.edu/archives/fall2009/entries/scientific-explanation/

Main questions:

a) What is the aim of Friedman's proposal?

b) What does Kitcher mean by an argument pattern and what is the function of argument patterns?

c) What is the relationship between the model of explanation by unification and the deductive-nomological model?

7) The current debate on Scientific Realism

Essential bibliography:

Chakravartty, Anjan (2011): Scientific Realism. In *The Stanford Encyclopedia of Philosophy (Summer 2011 Edition),* ed. E. N. Zalta. http://plato.stanford.edu/archives/sum2011/entries/scientific-realism/

Psillos, Stathis (1999): *Scientific Realism: How Science Tracks Truth*. New York: Routledge. Introduction & Chapters 5, 8, 9.

Kitcher, Philip (2001): "Real Realism: The Galilean Strategy". *The Philosophical Review*, 110: 151-197.

Laudan, Larry (1981): "A Confutation of Convergent Realism". *Philosophy of Science*, 48: 19-49.

Stanford, P. Kyle (2006): *Exceeding our Grasp: Science, History, and the Problem of Unconceived Alternatives*. New York: Oxford University Press.

Van Fraassen, Bas C. (1980): *The Scientific Image*. Oxford: Clarendon Press. Chapter 2.

Hacking, Ian (1983): *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science*. Cambridge University Press. Chapters 3 & 16.

Cartwright, Nancy (1983): *How the Laws of Physics Lie*. Oxford: Clarendon Press. Introduction & Essays 4 & 5.

Achinstein, Peter (2002): "Is There a Valid Experimental Argument for Scientific Realism?" *The Journal of Philosophy,* 99: 470-495.

Chakravartty, Anjan (2007): *A Metaphysics for Scientific Realism: Knowing the Unobservable*. Cambridge University Press. Chapters 1 & 2.

Main questions:

a) What is 'underdetermination of theory by evidence'? Is it only a problem within physics or does it also occur in other sciences? To what extent does it threaten scientific realism?

b) How can a realist respond to Laudan's 'pessimistic induction'? Is this response also valid against Stanford's 'new induction'?

c) Explain Van Fraassen's arguments against 'inference to the best explanation' and evaluate the responses given by Kitcher and Psillos.

d) Compare Hacking's, Cartwright's and Achinstein's attitudes towards 'inference to the best explanation' in their arguments for realism.

e) What are the differences between Psillos's realism and Chakravartty's 'semirealism'? Which of the two positions do you favour and why?