121 Advanced Philosophy of Physics: Reading List (MT24/HT25)

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This reading list suggests entrees into the following eight topics:

- Statistical Mechanics: Gibbs vs Boltzmann
- The Past Hypothesis
- Symmetry and Reality
- The Aharonov-Bohm Effect
- Noether's Theorem
- The Hole Argument
- The Local Validity of Special Relativity
- Energy in General Relativity

You should select six of them (in any order) for your tutorial essays. For each tutorial, please tell me at least five days beforehand which you are selecting, as well as the question you propose to answer in your essay, so that I can assess the question's suitability and, if needed, offer amendments. I am also happy to discuss briefly possible questions to propose.

In formulating the questions you will answer, keep in mind that you may be able to submit well-formulated questions to the Examination Board as approved topics for your examined essays. This would permit you to expand upon one of your tutorial essays for the examination. Note also that the examination regulations state that "Essays in Advanced Philosophy of Physics should avoid any substantial repetition of material between the two essays, and between either essay and the topics covered in 120 Intermediate Philosophy of Physics".

Statistical Mechanics: Gibbs vs Boltzmann

Reviews

Many of the following are comprehensive, but long. You might begin with the shorter pieces by Frigg and Werndl to first get a sense for the range of issues at a higher level.

- Frigg, Roman (2008). A field guide to recent work on the foundations of statistical mechanics. In Dean Rickles (ed.), *The Ashgate Companion to Contemporary Philosophy of Physics*. Ashgate. 99–196.
- Uffink, Jos (2007). Compendium of the foundations of classical statistical physics. In Jeremy Butterfield & John Earman (eds.), *Philosophy of Physics*. North-Holland. 923–1074.
- Frigg, Roman, and Charlotte Werndl (2021). Equilibrium in Boltzmannian statistical mechanics. In Eleanor Knox & Alastair Wilson (eds.), *The Routledge Companion to Philosophy of Physics*. Routledge. 403–413.
- Frigg, Roman, and Charlotte Werndl. Equilibrium in Gibbsian statistical mechanics. In Eleanor Knox & Alastair Wilson (eds.), *The Routledge Companion to Philosophy of Physics*. Routledge. 414–424.

- Frigg, Roman, and Charlotte Werndl (2023). *Foundations of Statistical Mechanics*. Cambridge UP.
- Frigg, Roman and Charlotte Werndl (2024), Philosophy of statistical mechanics. In Edward N. Zalta & Uri Nodelman (eds.), *The Stanford Encyclopedia of Philosophy* (Spring 2024 Edition). https://plato.stanford.edu/archives/spr2024/entries/statphys-statmech/.

Pro-Boltzmann

Most of the focus here is on the differing notions of thermodynamic equilibrium.

- Werndl, Charlotte & Roman Frigg (2017). Mind the gap: Boltzmannian versus Gibbsian equilibrium. *Philosophy of Science* 84(5), 1289–1302.
- Frigg, Roman & Charlotte Werndl (2019). Statistical mechanics: A tale of two theories. *The Monist* 102(4), 424–438.
- Lazarovici, Dustin (2019). On Boltzmann versus Gibbs and the equilibrium in statistical mechanics. *Philosophy of Science* 86(4), 785–793.

Pro-Gibbs

- Wallace, David (2020). The necessity of Gibbsian statistical mechanics. In Valia Allori (ed.), *Statistical Mechanics and Scientific Explanation*. World Scientific. 583–616.

Reconciliation

- Lavis, David A. (2005). Boltzmann and Gibbs: An attempted reconciliation. *Studies in History and Philosophy of Modern Physics* 36(2), 245–273.
- Lavis, David A. (2008). Boltzmann, Gibbs, and the concept of equilibrium. *Philosophy of Science* 75(5), 682–696.
- Myrvold, Wayne C. (2021). *Beyond Chance and Credence*. Oxford UP. Chapter 7.

The Past Hypothesis

This is an influential attempt to explain the direction of time by means of a certain initial condition for the universe. The line below follows chronologically some of the pro-con-pro discussion of this in this millennium.

- Albert, David Z (2000). *Time and Chance*. Harvard UP. Chapter 4
- Callender, Craig (2004). There is no puzzle about the low-entropy past. In Christopher Hitchcock (ed.), *Contemporary Debates in the Philosophy of Science*. Blackwell. 240–257.
- Callender, Craig (2004). Measures, explanations and the past: Should "special" initial conditions be explained? *British Journal for the Philosophy of Science* 55, 195–217.
- Parker, Daniel (2005). Thermodynamic irreversibility: Does the Big Bang explain what it purports to explain? *Philosophy of Science* 72(5), 751–763.
- Earman, John (2006). The "Past Hypothesis": Not even false. *Studies in the History and Philosophy of Modern Physics* 37, 399–430.
- Callender, Craig (2010). The Past Hypothesis meets gravity. In Gerhard Ernst & Andreas Hütteman (eds.), *Time, Chance and Reduction*. Cambridge UP. 34–58.
- Wallace, David (2023). The logic of the past hypothesis. In Barry Loewer, Brad Weslake & Eric B. Winsberg (eds.), *The Probability Map of the Universe*. Harvard UP. 76–109.

Symmetry and Reality

There is huge range of philosophical topics pertaining to symmetry. The general reviews cover many of them; I've added some focused reviews of more particular topics below.

General Reviews

- Brading, Katherine, Elena Castellani, & Nicholas Teh (2023). Symmetry and symmetry breaking. In Edward N. Zalta & Uri Nodelman (eds.), *The Stanford Encyclopedia of Philosophy* (Fall 2023 Edition). https://plato.stanford.edu/archives/fall2023/entries/symmetry-breaking/.
- Teh, Nicholas Joshua Yii Wye (2024). *The Philosophy of Symmetry*. Cambridge UP.
- Brading, Katherine & Elena Castellani (2007). Symmetries and invariances in classical physics. In Jeremy Butterfield & John Earman (eds.), *Philosophy of Physics*. North-Holland. 1331–1367.

Symmetry and Structure

- Baker, David (2010). Symmetry and the metaphysics of physics. *Philosophy Compass* 5(12), 157–166.
- Dasgupta, Shamik (2021). Symmetry and superfluous structure: A metaphysical overview. In Eleanor Knox & Alastair Wilson (eds.), *The Routledge Companion to Philosophy of Physics*. Routledge. 551–562.
- Ismael, Jenann (2021). Symmetry and superfluous structure: Lessons from history and tempered enthusiasm. In Eleanor Knox & Alastair Wilson (eds.), *The Routledge Companion to Philosophy of Physics*. Routledge. 563–577.

Symmetry Breaking

- Castellani, Elena, and Radin Dardashti (2021). Symmetry breaking. In Eleanor Knox & Alastair Wilson (eds.). *The Routledge Companion to Philosophy of Physics*. Routledge. 620–631.

Approximate Symmetry

- Fletcher, Samuel C. (2019). An invitation to approximate symmetry, with three applications to intertheoretic relations. *Synthese* 198(5), 4811–4831.

The Aharanov-Bohm effect

The Aharonov-Bohm effect seems to challenge the idea, natural from classical electromagnetism, that the exact value of the gauge potential isn't physically meaningful. The below reviews contain good reading lists to many ways to approach this topic. I've added some papers on another more recent approach focusing on the challenge as an inapt consequence of an idealization.

Reviews

- Harvey Brown's 2016 Notes
- Adam Caulton's 2018 Notes

The A-B effect and idealizations

- Elay, Shech (2018). Idealizations, essential self-adjointness, and minimal model explanation in the Aharonov–Bohm effect. *Synthese* 195(11), 4839–4863.
- Earman, John (2019). The role of idealizations in the Aharonov–Bohm effect. *Synthese* 196 (5), 1991–2019.

- Dougherty, John (2021). The non-ideal theory of the Aharonov–Bohm effect. *Synthese* 198(12), 12195–12221.

Noether's Theorems

Noether's theorems, proved by German mathematician Emmy Noether in 1918, provide a very general framework for how variational symmetries entail conservation laws. Many have invoked them to claim that symmetries therefore explain conservation laws. The most prominent philosophical line of analysis scrutinizes this claim (although there are other relevant topics to be found in the further reading).

Symmetry, Conservation, and Explanation

- Brading, Katherine & Harvey R. Brown (2002). Symmetries and Noether's theorems. In Katherine Brading & Elena Castellani (eds.), *Symmetries in Physics*. Cambridge UP. 89–109.
- Butterfield, Jeremy (2006). On symmetry and conserved quantities in classical mechanics. In William Demopoulos & Itamar Pitowsky (eds.), *Physical Theory and its Interpretation*. Springer. 43–100.
- Lange, Marc (2007). Laws and meta-laws of nature: Conservation laws and symmetries. *Studies in History and Philosophy of Modern Physics* 38(3), 457–481.
- Smith, Sheldon R. (2008). Symmetries and the explanation of conservation laws in the light of the inverse problem in Lagrangian mechanics. *Studies in History and Philosophy of Modern Physics* 39(2), 325–345.
- Brown, Harvey R. (2022). Do symmetries "explain" conservation laws? The modern converse Noether theorem vs pragmatism. In James Read & Nicholas J. Teh (eds.), *The Physics and Philosophy of Noether's theorems*. Cambridge UP.

Further Reading

- Read, James & Nicholas J. Teh, (eds.) (2022). *The Physics and Philosophy of Noether's Theorems*. Cambridge UP.
- Butterfield, Jeremy (2007). On symplectic reduction in classical mechanics. In Jeremy Butterfield & John Earman (eds.), *Philosophy of Physics*. North-Holland. 1–131.

The Hole Argument

The "Hole Argument" is an argument, a form of which Einstein found in his search for the field equation of what would become his general theory of relativity, that purports to draw ontological consequences about the nature of spacetime from naturalistic commitments about the theory.

Reviews

- Norton, John D., Oliver Pooley, and James Read (2023). The Hole Argument. In Edward N. Zalta & Uri Nodelman (eds.), *The Stanford Encyclopedia of Philosophy* (Summer 2023 Edition) https://plato.stanford.edu/archives/sum2023/entries/spacetime-holearg/.
- Pooley, Oliver (2021). The Hole Argument. In Eleanor Knox and Alastair Wilson (eds.), *The Routledge Companion to Philosophy of Physics*. Routledge. 145–159.

The Original Arguments and their History

- Earman, John & John D. Norton (1987). What price spacetime substantivalism? The hole story. *British Journal for the Philosophy of Science* 38, 515–525.
- Stachel, John (1989 [1980]). Einstein's search for general covariance. In Don Howard & John Stachel (eds.), *Einstein and the History of General Relativity*. Birkhäuser. 63–100.
- Weatherall, James Owen (2020). Some philosophical prehistory of the (Earman-Norton) hole argument. *Studies in History and Philosophy of Modern Physics* 70, 79–87.

Relational Responses

- Stachel, John (1993). The meaning of general covariance. In John Earman, Allan I. Janis, Gerald J. Massey, & Nicholas Rescher (eds.), *Philosophical Problems of the Internal and External Worlds*. University of Pittsburgh Press/ Universitaetsverlag Konstanz. 129–160.

Essentialist Responses

- Maudlin, Tim (1989). The essence of space-time. In Arthur Fine and Jarrett Leplin (eds.), *PSA 1988*, Volume 2, 82–91.
- Butterfield, Jeremy (1989). The hole truth. *British Journal for the Philosophy of Science* 40: 1–28.
- Teitel, Trevor (2019). Holes in spacetime: Some neglected essentials. *Journal of Philosophy* 116, 353–389.

Susbstantivalist Responses

- Brighouse, Carolyn (1994). Spacetime and holes. In D. Hull, M. Forbes and R. M. Burian (eds.), *PSA 1994*, Volume 1, 117–125.
- Hoefer, Carl (1996). The metaphysics of space-time substantivalism. *Journal of Philosophy* 93, 5–27.

Representational Responses

- Weatherall, James Owen. (2018). Regarding the 'Hole Argument.' *British Journal for the Philosophy of Science* 69(2), 329–350.
- Fletcher, Samuel C. (2020). On representational capacities, with an application to general relativity. *Foundations of Physics* 50, 228–249.
- Bradley, Clara, and James Owen Weatherall (2022). Mathematical responses to the hole argument: Then and now. *Philosophy of Science* 89(5), 1223-1232.
- Fletcher, Samuel C. (2024). *Foundations of General Relativity*. Cambridge UP. Section 3.4.

Further Reviews

- Earman, John (1989). *World Enough and Space-Time*. MIT/Bradford Press. Chapter 9.
- Stachel, John (2014). The Hole Argument and some physical and philosophical implications. *Living Reviews in Relativity* 17(1): available online.
- Pooley, Oliver (2013). Substantivalist and relationalist approaches to spacetime. In Robert W. Batterman (ed.), *The Oxford Handbook of Philosophy of Physics*. Oxford UP. 522–586.

The Local Validity of Special Relativity

What is the relationship between the special and general theories of relativity?

Review

- Lehmkuhl, Dennis (2021). The equivalence principle(s). In Eleanor Knox & Alastair Wilson (eds.), *The Routledge Companion to Philosophy of Physics*. Routledge. 125–144.

Recent line of analysis

- Ghins, Michel & Tim Budden (2001). The principle of equivalence. *Studies in History and Philosophy of Modern Physics* 32(1), 33–51.
- Knox, Eleanor (2013). Effective spacetime geometry. *Studies in History and Philosophy of Modern Physics* 44(3), 346–356. [Focus on section 3.]
- James Read, Harvey R. Brown and Dennis Lehmkuhl (2018). Two miracles of general relativity. *Studies in History and Philosophy of Modern Physics* 64, 14–25.
- Fletcher, Samuel C. (2020). Approximate local Poincaré spacetime symmetry in general relativity. In Claus Beisbart, Tilman Sauer, & Christian Wüthrich (eds.), *Thinking About Space and Time*. Birkhäuser. 247–267.
- Fletcher, Samuel C. & James Owen Weatherall (2023). The local validity of special relativity, part 1: Geometry. *Philosophy of Physics* 1(1), 7.
- Fletcher, Samuel C. & James Owen Weatherall (2023). The local validity of special relativity, part 2: Matter dynamics. *Philosophy of Physics* 1(1), 8.

Historical Review

- Norton, John (1985). What was Einstein's principle of equivalence? *Studies in History and Philosophy of Science* 16(3), 203–246.

Energy in General Relativity

Energy has a contested status in general relativity. It's sometimes claimed that, in that theory, energy is no longer conserved and that gravitational energy is no longer well-defined. In what relevant senses are claims like these true or false?

Reviews

- Fletcher, Samuel C. (2024). *Foundations of General Relativity*. Cambridge UP. Section 4.

Conservation

- Hoefer, Carl (2000). Energy conservation in GTR. *Studies in History and Philosophy of Modern Physics* 31(2), 187–199.
- Lam, Vincent (2011). Gravitational and nongravitational energy: The need for background structures. *Philosophy of Science* 78(5), 1012–1023.
- Duerr, Patrick M. (2019). Fantastic beasts and where (not) to find them: Local gravitational energy and energy conservation in general relativity. *Studies in History and Philosophy of Modern Physics* 65, 1–14.

Gravitational Energy

- Pitts, J. Brian. (2010). Gauge-invariant localization of infinitely many gravitational energies from all possible auxiliary structures. *General Relativity and Gravitation* 42, 601–622.

- Dewar, Neil, and James Owen Weatherall (2018). On gravitational energy in Newtonian theories. *Foundations of Physics* 48(5), 558–578.
- Curiel, Erik (2019). On geometric objects, the non-existence of a gravitational stress-energy tensor, and the uniqueness of the Einstein field equation. *Studies in History and Philosophy of Modern Physics* 66, 90-102.
- Read, James (2020). Functional gravitational energy. *British Journal for the Philosophy of Science* 71(1), 205–232.