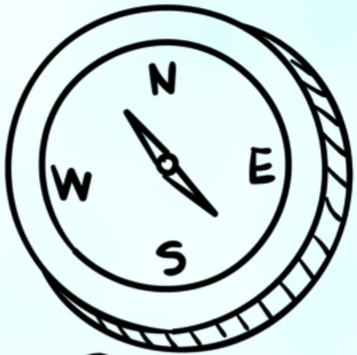
PHILOSOPHICAL FOUNDATIONS OF PHYSICS 146



Nature of Space and Time

Fall 2017, MWF 1:00
Solis Hall 109

Prof Craig Callender

This quarter the course will focus on the philosophical foundations of spacetime physics, both classical and relativistic. This topic is an exceptionally rich one, for it has attracted some of the all-time greatest thinkers in science and philosophy, e.g., Descartes, Galileo, Newton, Leibniz, Kant, Reichenbach, Einstein, Gödel. We'll focus on many deep questions, including the following: Are space and time (or spacetime) genuine substances? Does time “flow”? Does relativity prove that it doesn’t? What is the “shape” of space? Is physical geometry conventional in some sense? Is time travel possible or paradoxical? Does quantum nonlocality conflict with relativity? Tackling these questions will help one better understand both the physics of spacetime and the philosophy of science.

There is no prerequisite for the course. A tolerance for math is important, however, as we’ll dive into relativistic physics. Every effort will be made to present the physics as cleanly and accessibly as possible. Students without technical backgrounds can and do thrive in this course, so long as math anxiety is left behind.

146: Philosophical Foundations of Physics

Instructors

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Final Exam

Monday, 11:30a - 2:29p

Reading

Geroch, *General Relativity from A to B*
Maudlin*, Philosophy of Physics: Space and Time*
Free journal articles via Tritoned

Attendance

I guarantee that every single lecture will contain material not found in the reading—indeed, typically a lot of such material. Given all the quizzes, anything short of regular attendance will severely damage your grade.

Grade

8 short assignments/quizzes (8x5=40%), participation (5%), a midterm (25%) and a final examination (30%).

Fine Print

In your assignments, all sources must be appropriately acknowledged. All answers given must be in your own wording. Closely paraphrasing or simply copying the work of others (such as authors of books or articles, or classmates, or Wikipedia) is not allowed. Plagiarism, the stealing of an idea or actual text, and other forms of academic dishonesty will be immediately reported to the Academic Integrity Office. Students agree that by taking this course all required papers, quizzes and homework may be subject to submission for textual similarity review to Turnitin.com for the detection of plagiarism. Use of the Turnitin.com service is subject to the terms of use agreement posted on the Turnitin.com site. See the University's Policy on Integrity of Scholarship. Students who wish to take a make-up exam or hand in material late must inform me (by phone or email) well ahead of time. In order to qualify for a make-up exam, appropriate evidence of the most severe circumstances must be produced by the student. I will determine, in consultation with the student, what qualifies as appropriate evidence. Finally, texting, emailing, facebook, etc., during lecture is not allowed. For the most up-to-date schedule of readings, go to the TED site.

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Ancient and Classical Spacetimes. After warming up with Zeno's famous paradoxes of motion, students will be introduced to the necessary mathematical and physical concepts (especially the distinctions among topological, affine, and metrical transformations). We'll focus on how physics determines spatiotemporal structure, in particular, how properties of Aristotelian and Newtonian dynamics demand particular types of spatiotemporal structure. We'll then tackle two big philosophical topics, (a) Leibniz versus Clarke on whether space is absolute or a substance, and (b) Kant on handedness and space.

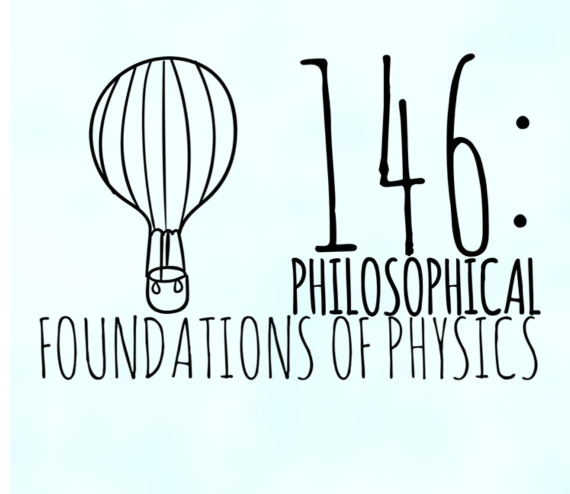
9-29	Introduction, Zeno's Paradoxes,
10-2	Zeno and Modern Mathematics Handout, Huggett, selections
10-4	Metrics, Topology, Coordinates, and All That Geroch, 3-36, Maudlin, 24-34
10-6	No class! Instead you're invited to Skepticism and Open-mindedness in Science Workshop
10-9	Newtonian Physics and Newtonian Spacetime Newton, *The Principia*, Scholium Geroch, 37-52 Maudlin 1-24
10-11 to 10-13	Leibniz vs Newton: Absolute, Relational and Substantival Space The Leibniz-Clarke Correspondence, selections (L2:1, C2:1, L3, C3:2-5, L4:3-7, 13) Maudlin, 34-46
10-16	Galilean Spacetime Maudlin, 47-66
10-18	Kant, Hands, Space Sklar, "Incongruous Counterparts, Intrinsic Features, and the Substantiviality of Space"

Minkowski Spacetime. In 1905 Einstein discovered the special theory of relativity. His supervisor, Minkowski, later developed the spacetime appropriate to this physics, Minkowski spacetime. After learning this theory, focusing especially on its basic assumptions and puzzles, e.g., the "twin paradox," we'll briefly revisit the Leibniz-Clarke debate and then turn to the question of whether time flows.

10-20 to 10-25	Special Relativity Einstein, "The Problem of Space, Ether and the Field in Physics" Geroch, 53-112 Special Relativity, Clocks, Barns, Twins, and All That Maudlin 67–126
10-27	Does Time Flow? Watch video: Is Time Real? Dyke, The Metaphysics of Time
10-30	Putnam, "Time and Physical Geometry"
11-1	Callender, What Makes Time Special? ch. 1 Hartle, "The Physics of Now"
11-3	MIDTERM

General Relativistic Spacetimes. Between 1912-1917 Einstein developed a theory that handles gravitational phenomena as well as electromagnetic phenomena. Crucially, gravitational "forces" are understood to be aspects of spatiotemporal curvature. Unlike special relativity, this theory is technically challenging — but we can obtain a great understanding of the causal structure of general relativistic spacetimes via Geroch even if leave the fancy differential geometry to another course. The rich variety of possible spacetimes permitted by GR raises many deep philosophical questions, new and old.

11-6	Gaussian Curvature and Non-Euclidean Geometry Handout
11-8 to 11-13	General Relativity Geroch 159-185, Maudlin 126-140
11- 10	No Class, Veteran's Day
11-15	Black Holes Geroch, chapter 8, Maudlin 140-146
11-17	The Epistemology of Geometry Ray, "A Conventional World?"
11-20	The "Uniformity" of Time Reichenbach, tbd
11-22	Magnus, "Reckoning the Shape of Everything" (Luminet, "A Cosmic Hall of Mirrors")
11-24	Time Travel: Conceptual Issues Lewis, "The Paradoxes of Time Travel"
11-27	Time Travel: Physical Issues Arntzenius & Maudlin, "Time Travel and Modern Physics" selections
11-29	Time Travel and Time Gödel, "A Remark About the Relationship between Relativity Theory and Idealistic Philosophy"



Quantum Theory. The class has so far focused on relativity theory, our best theory of the every large. But of course our best theory of the very small is quantum theory. We end by looking at the challenge facing physics as it tries to consistently marry the theory theories together. In particular, we'll explore the "spooky action at a distance" found experimentally in the violation of Bell's inequality.

12-1	tbd
12-4	tbd
12-6	tbd
12-8	Review for Final

Here are some suggestions for further rreading:

John Earman, World Enough and Spacetime
Nick Huggett, Space from Zeno to Einstein
Hans Reichenbach, The Philosophy of Space and Time
Lawrence Sklar, Space, Time, and Spacetime
Michael Friedman, Foundations of Space-Time Theories
Barry Dainton, Time and Space
Craig Callender, What Makes Time Special?
John Norton, Einstein for Everybody
John D. Norton, Einstein for Everyone, ebook, http://www.pitt.edu/~jdnorton/teaching/HPS_0410/chapters/index.html