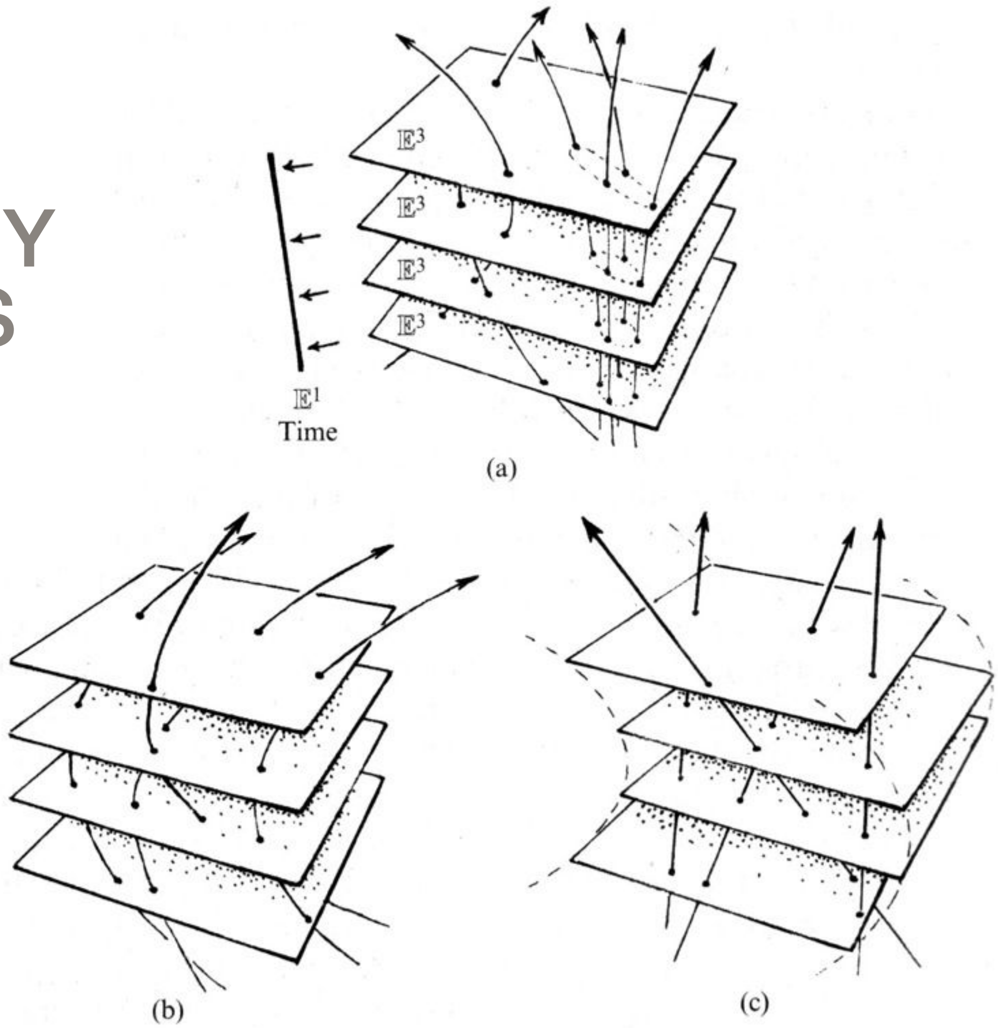
PHIL 146

PHILOSOPHY OF PHYSICS



Nature of Space and Time

Winter 2023,
TuTh 3:30-4:50
RWAC 426

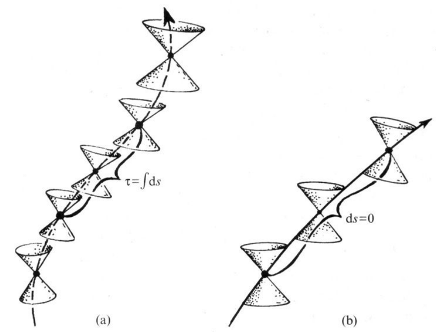
Prof Craig Callender

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: Are space and time (or spacetime) genuine substances? Does time "flow"? What is the "shape" of space? Is physical geometry conventional in some sense? Is time travel possible or paradoxical? Is relativity compatible with quantum non-locality? Tackling these questions will help one better understand both the physics of spacetime and the philosophy of science.

Our goals will be to understand this rich topic, learn some skills in philosophy and physics, and improve your critical thinking and writing.

Students without technical backgrounds can thrive in this course, so long as they have a tolerance for math.



Instructor

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Office hrs: Tues 230-330 and by appointment

Reading

Free journal articles, chapters, etc on Canvas.
Tim Maudlin, *Philosophy of Physics: Space and Time* (free @ UCSD library)
Robert Geroch, *General Relativity A to B*
I'll describe the reading each week in a Canvas announcement. It should be done before the relevant class. The readings below are subject to revision.

Prerequisites

No formal requirements. But a solid high-school physics or math background would be recommended. If you do not have much background in mathematics or physics, you need to be prepared to work hard on problem sets, look up extra resources, and be ready to seek help from classmates and instructor.

Attendance

Every single lecture will contain material not found in the reading—indeed, typically there will be a lot of such material. Given the nature of this course, anything short of regular attendance will severely damage your grade.

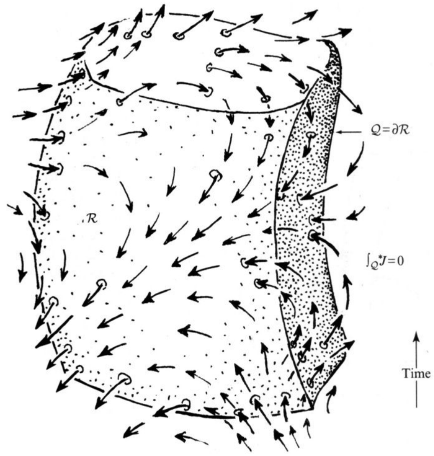
Grade

Short assignments and small class quizzes (30%), participation (5%), midterm (30%), final exam (35%). There is also an optional extra credit (5%) physical "mumbo jumbo" assignment. More info and details via Canvas and lecture.

Fine Print

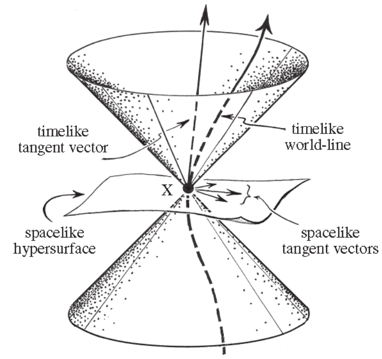
In your assignments all sources must be appropriately acknowledged. All answers given must be in your own wording. Closely paraphrasing or simply copying the work of others (such as authors of books or articles, or classmates, or Wikipedia) is not allowed. Plagiarism, the stealing of an idea or actual 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. For official policy see www.senate.ucsd.edu/manual/appendices/app2.htm. Students who wish to hand in material late must inform me (by email) well ahead of time. In order to qualify for late hand in's of assignments, 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. Students requesting accommodations for the course must produce an AFA letter from OSD. OSD can be called at 858-534-4382.

Ancient and Classical Spacetimes. We'll warm up with Zeno's famous paradoxes of motion. Students then will be introduced to the mathematical and physical concepts (especially the distinctions among topological, affine, and metrical transformations) we'll need. 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/ substantial, and (b) Kant on handedness and space.



1-10	Introduction, Zeno's Paradoxes Huggett selection, *Space: From Zeno to Einstein*, ch 3 (Zeno) Handout
1-12	Zeno's Paradoxes Huggett selection continued Laraudogoitia, A Beautiful Supertask
1-17	Metrics, Topology, Coordinates, and All That Geroch, 3-36, Maudlin, 24-34
1-19	Newtonian Physics and Newtonian Spacetime Newton, *The Principia*, <u>Scholium</u> Geroch, 37-52 Maudlin 1-24
1-24	Leibniz vs Newton: Absolute, Relational and Substantival Space The Leibniz-Clarke Correspondence, <u>selections</u> (L2:1, C2:1, L3, C3:2-5, L4:3-7, 13) Maudlin, 34-46
1-26	Galilean Spacetime and A Peek at Recent Developments Maudlin, 47-66 Barbour, Shape Dynamics, TBD
1-31	Kant, Hands, Space Huggett, ch 11

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.



2-2 Special Relativity

2-7 Geroch, 53-112; Maudlin 67–126

Extra: Uzan et al, Twin Paradox and Space Topology

2-9 Does Time Flow?

Deng, The Metaphysics of Time

Callender, What Makes Time Special? selection

Is Time Real?

2-14 Relativity and Time Flow

Putnam, Time and Physical Geometry

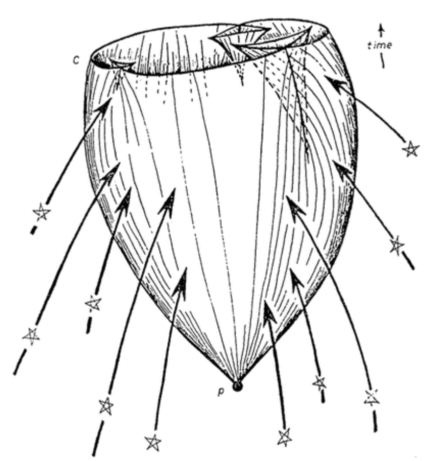
Hartle, The Physics of Now

2-16 Time Travel I

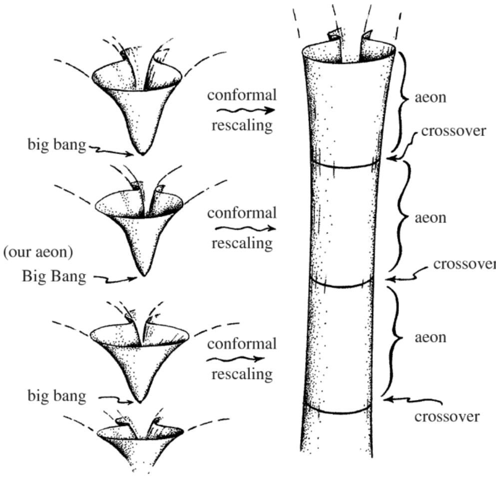
Lewis, The Paradoxes of Time Travel

2-21 MIDTERM (in-person)

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.



2-23	General Relativity Geroch 159-185, Maudlin 126-140 Handout: Gaussian curvature
2-28	Time Travel II Gödel, "A Remark…"
3-2	The Epistemology of Geometry I Poincare, The Uniformity of Time Norton, chapter 5, section 5.2
3-7	The Epistemology of Geometry II Ray, A Conventional World? Magnus, Reckoning the Shape of Everything: Underdetermination and Cosmotopology
3-9	Weird Stuff: Black Holes and Horizons Geroch, chapter 8, Maudlin 140-146 Callender and Hoefer, section
3-14	Weird Stuff: Quantum Non-locality Maudlin, TBD
3-16	Review



Here are some suggestions for further reading:

Julian Barbour, *The End of Time*
Craig Callender, *What Makes Time Special?*
Craig Callender, *Introducing Time*
Barry Dainton, *Time and Space*
John Earman, *World Enough and Spacetime*
John Earman, *Bangs, Crunches, Whimpers and Shrieks*
Michael Friedman, *Foundations of Space-Time Theories*
Nick Huggett, *Space from Zeno to Einstein*
David Malament, *Topics in the Foundations of General relativity and Newtonian Gravitation Theory*
John Norton, Einstein for Everybody
Hans Reichenbach, *The Philosophy of Space and Time*
Lawrence Sklar, *Space, Time, and Spacetime*