Topics in Philosophy of Physics: Philosophy of Space and Time

Philosophy 426

T 1:10-4:10pm, 210 Miller Hall

J. North (j.north@rutgers.edu)

We will focus on the following question. Do space and time exist in addition to material objects? In modern terms: does spacetime exist? We will look at historical and contemporary arguments from physics and philosophy. One theme will be that it is not clear what the traditional debate amounts to, nor whether it is a substantive dispute. Our aim is to better understand this dispute and how it could be decided in favor of one side or the other. Time and student interest permitting, we may discuss related issues in the philosophy of space and time.

Readings

Required books, available at the bookstore
(`https://tinyurl.com/F18-Course-Material-730426`)
and on reserve at the Alexander Library undergraduate circulation desk:

John Earman, *World Enough and Space-Time*
Robert Geroch, *General Relativity from A to B*
Nick Huggett, *Space from Zeno to Einstein*
Tim Maudlin, *Philosophy of Physics: Space and Time*
Hans Reichenbach, *The Philosophy of Space and Time*

Optional books (at the bookstore and on reserve at Alexander):

Michael Friedman, *Foundations of Space-Time Theories*
Lawrence Sklar, *Space, Time, and Spacetime*

All other readings are available at the course website (address given out in class)

Prerequisites

I will assume that you have had some high school physics (for instance, $F = ma$ should be familiar to you), but this needn't be at your fingertips. I assume no background in philosophy, although one previous course is recommended.

Requirements and grading

Reading, attendance, participation, and homework. Required reading for each class. Participation and attendance count for 10% of your final grade. Participation in class discussion can only help your grade; lack of participation won't hurt your grade. Attendance is mandatory. Note that if you miss a class, it is *your responsibility* to get notes and announcements from a classmate.

Written work. Take-home midterm and final exams. Each exam will consist of five questions with two-page answers each. The midterm exam will be handed out in class October 16 and due in class October 30; it counts for 40% of your grade. The final exam will be handed out in the last class, December 11 and due by 5pm December 18; it counts for 50% of your grade. (By special permission, you may choose to write a final 10-page paper instead of the final exam. Paper topics, with an outline and list of readings, must be cleared with me in advance.)

Academic integrity

Each student in this course is expected to abide by the Rutgers University Principles of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work. For this course, collaboration is allowed in discussing paper topics and exam questions. Papers and exams submitted for credit must be entirely your own work. If you quote or use an idea from another source, *you must cite it*. More information on Rutgers' Principles of Academic Integrity is here: http://academicintegrity.rutgers.edu

Course materials posted on the course website or handed out in hard copy are intellectual property belonging to the author. Students are not permitted to buy or sell any course materials without the express permission of the instructor. Such unauthorized behavior constitutes academic misconduct.

Office Hours

Thursday 1-2pm, 106 Somerset St. room 530

Schedule

Details are subject to change during the semester. Readings are listed by the date on which they will be discussed. The last class has been left open. It will either be catch-up or on a topic determined by student interest.

September 4: Introduction to the traditional debate

Overview of the historical debate. The connection between objects' motions and the existence of space and time. Different senses of the various terms and concepts used in the traditional debate. Newton's laws and Newtonian physics.

Reading: Earman, Introduction and ch. 1; Huggett, "Space in Physical Theories"; Albert, "Time-Reversal Invariance" excerpt

Optional: Huggett, chs. 4, 6; Huggett and Hoefer, "Absolute and Relational Theories of Space and Motion," at:

http://plato.stanford.edu/entries/spacetime-theories/

September 11: Classical spacetime

Spacetime geometry and different classical spacetime structures; Galilean and Aristotelian spacetimes. The relation between spacetime structure and different quantities of motion. Newton's laws in spacetime terms. Structure and invariant quantities; frame- or coordinate-dependent quantities; invariance and objectivity. The traditional debate in spacetime terms.

Reading: Geroch, chs. 1-3; Maudlin, "Relativity and Space-Time Structure" through p. 39

Optional: Earman, ch. 2; Huggett, ch. 10

September 18: Newton's bucket and globes

Newton's arguments for absolute space; bucket experiment, spinning globes; various replies. Aristotelian vs. Galilean spacetime for Newtonian physics.

Reading: Earman, 4.1; Huggett, ch. 7 commentary; Maudlin, through p. 34; Maudlin, "Buckets of Water and Waves of Space: Why Spacetime is Probably a Substance" sec. 2

Optional: Earman, rest of ch. 4; Friedman, ch. 1; Huggett, rest of ch. 7; Knox, "Newtonian Spacetime Structure in Light of the Equivalence Principle"

September 25: Leibniz shifts

The static and kinematic shift arguments for relationalism; various replies.

Reading: Earman, ch. 6; Huggett, ch. 8 commentary; Maudlin, pp. 35-54

Optional: Huggett, rest of ch. 8; Maudlin, "Buckets" sec. 3; Dasgupta, "Substantivalism vs. Relationalism about Space in Classical Physics" sec. 9

October 2: Kant and handedness

Kant's argument for substantivalism; accounting for handed objects and parity-violating behavior in general; modal relationalism; relationalism and non-local explanation. Relationalism vs. substantivalism for classical physics.

Reading: Earman, ch. 7; Huggett, ch. 11 commentary; Arntzenius, "Do Space and Time Exist?" sec. 5.4

Optional: Brighouse, "Incongruent Counterparts and Modal Relationism" (recommended: read it if you have time); Huggett, rest of ch. 11; Pooley, "Handedness, Parity Violation, and the Reality of Space"

October 9: Special relativity

Overview of special relativity. Constancy of speed of light; consequences of the relativity of simultaneity; Lorentz transformations; invariant and frame-dependent quantities in special relativity; Minkowski spacetime and the spacetime interval. Relationalism vs. substantivalism for special relativity.

Reading: Geroch, chs. 4-5; Maudlin, "Relativity and Space-Time Structure" starting from p. 40; Maudlin, ch. 4 through p. 87

Optional: Geroch, ch. 6; Maudlin, chs. 4-5; Maudlin, "Buckets of Water and Waves of Space" sec. 5

October 16: Choosing a spacetime structure

Midterm exam handed out in class; due in class October 30.

How do we pick a spacetime structure for the physics? How does this relate to the question of the existence of spacetime? Symmetry considerations; empirical detectability arguments; levels of structure; choosing different structures for a physical theory. Examples of choosing a spacetime structure for Newtonian physics and for special relativity.

Reading: Earman, ch. 3 through p. 49; Maudlin, ch. 3 starting from p. 54 (and see again pp. 5-8); North, "The 'Structure' of Physics: A Case Study" sec. 1 (pp. 59-67) and "Classical Mechanics, Structure, and The World" sec. 2

Optional: Brading and Castellani, "Symmetries and Invariances in Classical Physics"; Earman, ch. 2; Ismael and van Fraassen, "Symmetry as a Guide to Superfluous Theoretical Structure"

October 23: General relativity

Geometry on curved surfaces. Gravity as the manifestation of spacetime curvature; the metric in general relativity; Einstein's equation; vacuum spacetimes and gravitational waves. Relationalism vs. substantivalism in general relativity.

Reading: Geroch, ch. 7; Huggett, 12.4; Maudlin, "Life in Elastic Space-Time" pp. 223-227, ch. 6 through p. 140, and "Buckets of Water and Waves of Space" secs. 6-7

Optional: Huggett ch. 14; Geroch ch. 8; Maudlin ch. 6 pp. 140-146

October 30: Conventionalism

Midterm due in class.

Can we know the structure of a world's spacetime? Geometry in curved spaces and spacetimes; epistemology of geometry; underdetermination; convention.

Reading: Huggett, ch. 2, ch. 13 commentary; Reichenbach, ch. 1 secs. 1-12

Optional: Huggett, rest of ch. 13; Friedman, *Foundations of Space-Time Theories* ch. 1

November 6: The hole argument

A new argument against substantivalism; diffeomorphism invariance in general relativity; determinism and indeterminism; replies to the hole argument.

Reading: Earman and Norton, "What Price Space-Time Substantivalism? The Hole Story" (skip sec. 2, but see the "gauge theorem" on p. 520); Norton, secs. 1-7 of http://plato.stanford.edu/entries/spacetime-holearg/; Brighouse, "Spacetime and Holes"; Maudlin ch. 6 pp. 146-151

Optional: Arntzenius, "Do Space and Time Exist?" sec. 5.12; Dasgupta, "The Bare Necessities"; Earman ch. 9; Hoefer, "The Metaphysics of Space-Time Substantivalism"; Hoefer, "Causal Determinism" (esp. sec. 4.1), at

http://plato.stanford.edu/entries/determinism-causal/

November 13: NO CLASS

November 27: Other modern debates

Other more recent considerations in the debate and more recent conceptions of substantivalism and relationalism. The debate about fields. Vacuum worlds; embedding strategies. Is the debate about spacetime ontology substantive?

Reading: Field "Can We Dispense with Space-Time?" sec. 3; Rynasiewicz, "Absolute Versus Relational Space-Time: An Outmoded Debate?"; Hoefer, "Absolute versus Relational Spacetime: For Better or Worse, the Debate Goes On" (skip sec. 3.2)

Optional: Arntzenius, "Do Space and Time Exist?" sec. 5.5; Belot, "Geometry and Motion"; Earman ch. 8; rest of Field, "Can We Dispense"; Hoefer, "The Metaphysics of Space-Time Substantivalism"; Malament, review of Field *Science Without Numbers* pp. 531-2; Maudlin "Buckets" sec. 4

December 4: An updated debate

A new conception of the debate about spacetime and a new argument for substantivalism; fundamental and nonfundamental ontology and laws; ground; spatiotemporal structure; intrinsic and extrinsic explanations and formulations.

Reading: Fine, "Guide to Ground" secs. 1.1-1.2; North, "A New Approach to the Relational-Substantival Debate"

Optional: Hicks and Schaffer, "Derivative Properties in Fundamental Laws"; Nagel, "Issues in the Logic of Reductive Explanations"; North, "Time in Thermodynamics" (for background on the debate involving the Past Hypothesis); Rosen, "Metaphysical Dependence" secs. 1-3

December 11: TBD

Final exam handed out in class; final assignments due by 5pm December 18.