# Topics in Philosophy of Physics: Philosophy of Space and Time

Philosophy 426/658

Th 9:50am-12:50pm, 106 Somerset St. room 524B

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

## Readings

Required books (available at the bookstore and on reserve at Alexander Library's 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 top-secret course website
`https://courses.cit.cornell.edu/north/Phil_ST/Phil_ST.html`

## 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.* Three options:

1. Take-home midterm and final exams. Each exam will consist of around five questions with two-page answers each. The midterm exam will be handed out in class October 15 and due in class October 29; it counts for 40% of your grade. The final exam will be handed out in class December 10 and due by 5pm December 20; it counts for 50% of your grade.

2. Take-home midterm exam as above (40% of your grade) and final paper of around 10 pages on a topic of your choice, due by 5pm December 20 (50% of your grade).

3. One final paper, around 20 pages, on a topic of your choice, due by 5pm December 20 (90% of grade).

Options 1 and 2 are open to all students in the class. Option 3 is reserved for graduate students except in special cases; if you are an undergraduate interested in this option, you need to get my approval early in the semester. Paper topics for options 2 and 3 must be cleared with me in advance. *Turn in your work on time; I will not accept late papers or exams except in extraordinary circumstances.*

### 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 can be found 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 1:00-2:00, 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 will either be catch-up or on a topic determined by student interest.

Class 1, September 3: 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/

Class 2, September 10: 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

Class 3, September 17: 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; Huggett, rest of ch. 7; Knox, "Newtonian Spacetime Structure in Light of the Equivalence Principle"

Class 4, September 24: 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

Class 5, October 1: 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: do read it if you have time); Huggett, rest of ch. 11; Pooley, "Handedness, Parity Violation, and the Reality of Space"

Class 6, October 8: 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

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

Class 7, October 15: CHOOSING A SPACETIME STRUCTURE

*Midterm exam handed out in class; due in class October 29.*

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 22: NO CLASS

Class 8, October 29: GENERAL RELATIVITY

*Midterm exam due in class.*

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

Class 9, November 5: CONVENTIONALISM

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

Class 10, November 12: 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/

Class 11, November 19: 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

Class 12, December 3: AN UPDATED DEBATE

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

*Reading*: Fine, "Guide to Ground" secs. 1.1-1.2; North, "The Structure of Spacetime: A New Approach to the Spacetime Ontology 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

Class 13, December 10: TBD

*Final exam handed out in class; final assignments due by 5pm December 20.*
This will either be a catch-up day or we will discuss a topic to be determined by student interest. Possible topics include: other relationalist accounts (Descartes, Barbour, Huggett); Field's take on the debate; modal relationalism; spacetime structural realism; the debate in the context of quantum gravity; supersubstantivalism; the passage of time; presentism and spacetime structure; the difference between space and time.