Philosophy 226: Introduction to Philosophy of Physics

Fall 2026

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Friday 10:20am-1:20pm, 106 Somerset St. 5th floor

This course is an introduction to a variety of philosophical issues that arise in the context of classical (nonquantum) physics, including the nature of instantaneous velocity; the truth of the physical laws; the question of determinism; the existence of forces; the direction of time; the existence of space and time; the nature of spacetime; the flow of time; the possibility of time travel. Readings will be drawn from both physics and philosophy.

Readings

Book: R. Geroch, *General Relativity from A to B*

Other readings are available on the Canvas course site

Optional books:

D. Albert, *Time and Chance*

S. Carroll, *From Eternity to Here*

Feynman, Leighton, Sands, *The Feynman Lectures on Physics, Volume I* (available at `https://www.feynmanlectures.caltech.edu`)

B. Greene, *The Fabric of the Cosmos*

N. Huggett, *Space from Zeno to Einstein: Classic Readings with a Contemporary Commentary*

T. Maudlin, *Philosophy of Physics: Space and Time*

Prerequisites

Some exposure to physics, particularly Newtonian mechanics and gravitation, at either a high school or college level.

Requirements and grading

Reading for each class: Assigned readings will not be very long, but they can be difficult. It is recommended that you read each assignment through once before class and then again after it is discussed.

Attendance, participation, super-short weekly quizzes: 25% of your final grade.

Quizzes (15%) will be very short comprehension checks—a few questions with one-sentence answers each—during the first 10 minutes of each class period, and will cover the material discussed in class the previous week. The lowest quiz grade will be dropped. *Quizzes cannot be made up. The quiz period will close after the first 15 minutes of class: make every effort to be on time.*

Attendance and participation (10%) are mandatory. Since quiz and exam questions will be based on what we cover in class, poor attendance is bound to lower your grade. Note that if you miss a class, it is *your responsibility* to get notes and announcements from a classmate.

Two midterm exams: in-class, non-cumulative; each 20% of your final grade.

In-class final: cumulative; 35% of your final grade.

Electronic devices

There is a no-device policy for this class. All electronic devices must be silenced and stowed away during class time. Exceptions will be made for needed accommodations; please discuss with me.

Office hours

Friday 1:30-2:30pm or by appointment, 106 Somerset St. room 530.

Academic integrity

No use of generative AI tools is permitted and their use for any part of your work for this class will be treated as plagiarism.

Each student in this course is expected to abide by the Rutgers University Principles of Academic Integrity. Rutgers' Academic Integrity Policy (10.2.13) states that students must ensure "that all work submitted in a course, academic research, or other activity is the student's own and created without the aid of impermissible technologies, materials, or collaborations." Any work submitted by a student in this course for academic credit will be the student's own work. 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.

Schedule

Readings are listed by the date they will be discussed. Details are subject to change during the semester. The syllabus will be updated as needed.

Sept. 4: Instantaneous velocity

Introduction to the philosophy of physics. Zeno's arrow paradox and the existence of instantaneous velocity. Neighborhood quantities; impetus; intrinsic velocity; gunky space and time; geometry without points.

Reading: Ruetsche, "Philosophy of Physical Sciences"; Arntzenius, "Are There Really Instantaneous Velocities?" through the top of p. 197 and "Pointlessness" secs. 1–3 and 6

Optional: J. Carroll, "Instantaneous Motion" sec. 1; Greene ch. 1; Huggett ch. 3

Sept. 11: Scientific realism and the truth of the laws

Realism and antirealism and some traditional considerations. The observable-unobservable distinction; idealizations and approximations; forces and vectors; component forces; laws and capacities.

Reading: Maxwell, "The Ontological Status of Theoretical Entities"; Cartwright, "Do the Laws of Physics State the Facts?" (skip sec. 3)

Optional: Carroll, "Laws of Nature,"
`https://plato.stanford.edu/entries/laws-of-nature/`;
Chakravartty, "Scientific Realism,"
`https://plato.stanford.edu/entries/scientific-realism/`;
Van Fraassen, "Arguments Concerning Scientific Realism"

Sept. 18: Do Newtonian forces exist?

Newtonian forces; fundamental versus nonfundamental theories and ontology. Newtonian particle mechanics and other versions of classical mechanics. Different theoretical formulations as a threat to scientific realism. Metaphysical and mathematical differences between theories.

Reading: Wilson, "Newtonian Forces" secs. 1–4 (skip 2.3); Jones, "Realism about What?" secs. 1–3; North, "Formulations of Classical Mechanics"

Optional: Ruetsche, "Getting Real about Quantum Mechanics"

Sept. 25: Determinism and time-reversal invariance

Is Newtonian mechanics deterministic as usually claimed? Is it time-reversal invariant? Space invaders; Norton's dome; time reversal invariance; idealizations; conservation laws. Friction and dissipative forces; conservation of energy. What counts as a Newtonian system?

Reading: Albert, "Time-Reversal Invariance" secs. 1–2; Hoefer, "Causal Determinism" sec. 4.1, at
https://plato.stanford.edu/entries/determinism-causal/#ClaMec; Hutchison, "Is Classical Mechanics Really Time-Reversible and Deterministic?" secs. 1–5; Norton, "The Dome: An Unexpectedly Simple Failure of Determinism"

Optional: Malament, "Norton's Slippery Slope"; Norton, "The Dome: A Simple Violation of Determinism in Newtonian Mechanics," at
https://sites.pitt.edu/~jdnorton/Goodies/Dome/index.html

Oct. 2: Midterm 1

The midterm will be held during the first half of the class period. It will consist of short-essay questions on the material covered in class so far.

Oct. 9: The direction of time

The problem of the direction of time; time-asymmetry of experience and time reversal invariant dynamics. Thermodynamics and statistical mechanics; entropy and the second law; Maxwell's demon. The past hypothesis; Boltzmann brains; explaining initial conditions.

Reading: Greene, "Chance and the Arrow" (*Fabric* ch. 6); S. Carroll, excerpts from *From Eternity to Here*

Optional: Albert chs. 2–5; Callender, "There Is No Puzzle about the Low-Entropy Past"; Carroll, *From Eternity to Here*; Feynman "The Distinction of Past and Future"; Goldstein, "Boltzmann's Approach to Statistical Mechanics"

Oct. 16: Newton's bucket; classical spacetime

Does space exist? Relationalism versus substantivalism; Newton's bucket argument and spinning globes. Spacetime in a classical setting: events and worldlines; frames of reference, coordinate systems, coordinate transformations; invariant and frame-dependent quantities; Aristotelian and Galilean views.

Reading: Greene, "The Universe and the Bucket" (*Fabric* ch. 2); Geroch through ch. 3 (to be continued next week)

Optional: Huggett chs. 7, 9, 10; Maudlin ch. 2 through p. 34

Oct. 23: Leibniz shifts; Kant's glove

Static and kinematic Leibniz shift arguments for relationalism; counting possibilities. Kant's chirality argument; the nature of handedness. Relationalism

and substantivalism in the context of classical physics.

Reading: Finish Geroch through ch. 3; Huggett, "Leibniz and Clarke: Commentary" (in *Zeno to Einstein* ch. 8) and "Kant and Handedness: Commentary" (ch. 11); Maudlin, "Buckets of Water and Waves of Space" sec. 3

Optional: Maudlin ch. 2 from p. 34 and ch. 3

Oct. 30: Special relativity and the difference between space and time

The physics of special relativity. Constancy of light; relativity of simultaneity; Lorentz transformations; invariant and non-invariant quantities; length contraction and time dilation. Minkowski spacetime and the spacetime interval; light cones; clock postulate; twin paradox. Does special relativity eradicate the difference between space and time? If not, in what way are they different?

Reading: Demarest, "Time in Special Relativity" secs. 1–3; Geroch chs. 4–5; Maudlin, "Relativity and Space-Time Structure"; Skow, "What Makes Time Different from Space?" secs. 1–6

Optional: Maudlin chs. 4–5

Nov. 6: Midterm 2

The midterm will be held during the first half of the class period. It will consist of short-essay questions on material covered in class since the first midterm.

Nov. 13: The flow of time and the specialness of the present

Further philosophical issues arising from the nature of time in special relativity. The flow of time; time in physics, time in experience; frame-dependent features, frame-independent features, and physical reality; the manifest and scientific images. Presentism and the reality of the present, past, and future.

Reading: Greene "The Frozen River" (*Fabric* ch. 5); Ismael and Price, "Stubbornly Persistent Illusions"; Ismael, "Passage, Flow, and the Logic of Temporal Perspectives"; Sider, "Against Presentism" sec. 4

Optional: Hawley, "Science as a Guide to Metaphysics?"; Maudlin, "On the Passing of Time"; Paul, "Temporal Experience"

Nov. 20: General relativity and spacetime ontology

Geometry of curved spaces; gravity as a manifestation of spacetime curvature; spacetime metric; Einstein's field equations; light cones in curved spacetimes. Different general relativistic spacetime structures; black holes; vacuum solutions; gravitational waves. Relationalism and substantivalism in special and

general relativity.

Reading: Geroch chs. 7–8; Maudlin, "Buckets of Water and Waves of Space" secs. 6–7

Optional: Greene ch. 3; Huggett ch. 14; Maudlin ch. 6; North, "A New Approach to the Relational-Substantival Debate"

Nov. 25: Conventionalism

Can we empirically discover the structure of spacetime? Geometry in curved spaces and spacetimes. Conventionalism about spacetime structure. Empiricism; underdetermination; convention.

Reading: Gowers, "Geometry," ch. 6 of *Mathematics: A Very Short Introduction*; Reichenbach, excerpts from *The Philosophy of Space and Time*

Optional: Huggett chs. 2, 13

Dec. 4: Time travel

The paradoxes of time travel; personal and external time. Spacetimes that seem to allow for time travel; the possibility and the likelihood of time travel. The relationship between philosophy of science, metaphysics, and physics.

Some of this class meeting may be spent catching up, reviewing material, or discussing a further topic, depending on student interest and our progress during the semester.

Reading: Lewis, "The Paradoxes of Time Travel"; Arntzenius, "Time Travel: Double Your Fun" secs. 1–4; Dyke, "The Metaphysics and Epistemology of Time Travel"

Optional: Callender, "Philosophy of Science and Metaphysics"; Greene ch. 15; Maudlin ch. 7

Final exam: Friday, December 18, 9–11am.

Cumulative; short-essay questions on all the material from the semester.