Philosophy 226: Introduction to Philosophy of Physics

Fall 2023
TF 12:10–1:30pm, Scott Hall 115
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This course is an introduction to a variety of topics in the philosophy of physics, including Zeno's paradoxes of motion; the truth of the physical laws; determinism; the existence of forces; the nature and existence of space and time; the structure of spacetime; the possibility of time travel. Readings will be drawn from both physics and philosophy.

Readings

Required books:

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

B. Greene, *The Fabric of the Cosmos*

Optional book:

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

Other readings are available on the Canvas course website

Prerequisites

One semester of physics (01:750:115 or 01:750:123 or 01:750:161 or 01:750:193 or 01:750:201 or 01:750:203 or 01:750:271) or by permission of the instructor.

Requirements and Grading

Attendance and participation; reading: 10% of your final grade. Attendance is mandatory. Since exam questions will be based on material covered in class, poor attendance is likely to lower your grade. You must do the readings before each class carefully, and come prepared with questions and ideas to discuss. (Note that if you miss a class it is *your responsibility* to get notes and announcements from a classmate.). *Exams*: Three in-class midterms (non-cumulative, 20% each) and one take-home final (cumulative, 30% of your final grade).

Office hours

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

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.

Schedule

Details are subject to change during the semester. Readings are listed by the date they will be discussed in class.

Sept. 5: Introduction

Overview of the class; introduction to Zeno's puzzle.

Reading: Loewer, "Philosophy of Physics"; Ruetsche, "Philosophy of Physical Sciences"

(*Optional:* Greene ch. 1)

Sept. 8 Zeno's paradox

Zeno's paradox and replies; the existence and definition of instantaneous velocity; neighborhood quantities; impetus; intrinsic velocity.

Reading: Arntzenius, "Are There Really Instantaneous Velocities?" through the end of the first full paragraph on p. 197

(*Optional:* J. Carroll, "Instantaneous Motion"; Feynman ch. 8)

Sept. 12: Newtonian mechanics

Review of Newton's laws of motion and gravitation; force, acceleration, momentum. The atomic hypothesis; energy conservation; determinism; symmetries in general, time reversal symmetry in particular; the debate over time reversal invariance. The fundamental nature of a Newtonian world.

Reading: Albert, "Time-Reversal Invariance"

(*Optional*: Feynman chs. 4, 9, 10, 11, 52.1–52.2)

Sept. 15: Are the laws of physics true?

Idealizations and approximations in Newtonian mechanics and physics more generally. Forces and vectors; component forces; laws and capacities.

Reading: Cartwright, "Do the Laws of Physics State the Facts?" (skip sec. 3)

(*Optional*: Feynman chs. 7, 12)

Sept. 19: Do Newtonian forces exist?

Newtonian forces; energy; realism and instrumentalism; unobservable entities and theoretical posits; fundamental versus nonfundamental theories and ontology; formulations of classical mechanics.

Reading: Wilson, "Newtonian Forces" secs. 1–4 (skip section 2.3)

(*Optional*: Feynman ch. 13)

Sept. 22: Scientific realism

Realism versus antirealism about scientific theories and considerations in favor of each; the observable-unobservable distinction.

Reading: Maxwell, "The Ontological Status of Theoretical Entities"

(*Optional*: Chakravartty, "Scientific Realism," available at `https://plato.stanford.edu/entries/scientific-realism/`)

Sept. 26: Different formulations of classical mechanics

Newtonian particle mechanics and other versions of classical mechanics; Lagrangian and Hamiltonian mechanics. Metaphysical and mathematical differences between theories; the equivalence of theories. Do different formulations of a theory pose a threat to scientific realism?

Reading: Jones, "Realism about What?" secs. 1–3; North, "Formulations of Classical Mechanics"

(*Optional*: Ruetsche, "Getting Real about Quantum Mechanics")

Sept. 29: Is Newtonian mechanics deterministic?

Space invaders and Norton's dome; time reversal symmetry; idealizations; conservation laws. What counts as a Newtonian system?

Reading: Section 4.1 of Hoefer, "Causal Determinism," available at `https://plato.stanford.edu/entries/determinism-causal/`

Norton, "The Dome: A Simple Violation of Determinism in Newtonian Mechanics," available at

http://www.pitt.edu/~jdnorton/Goodies/Dome/index.html

Oct. 3: Midterm 1 in class

Oct. 6: Is Newtonian mechanics time reversal invariant?

Friction and dissipative forces; conservation of energy; the question of time reversal invariance.

Reading: Hutchison, "Is Classical Mechanics Really Time-Reversible and Deterministic?" (skip secs. 6–7)

(*Optional*: Feynman 14.1–14.4)

Oct. 10 and 13: The direction of time

How can we explain the prevalence of temporally asymmetry phenomena in a world with time reversal symmetric laws? Macroscopic asymmetries and the direction of time; thermodynamics and statistical mechanics; entropy and the second law; Maxwell's demon; the past hypothesis and objections.

Reading: Greene ch. 6; S. Carroll, excerpts from *From Eternity to Here*

(*Optional*: *Reading*: Feynman chs. 39, 44, 46 and "The Distinction of Past and Future")

Oct. 17: Classical spacetime

Non-relativistic spacetime; events and worldlines; frames of reference, coordinate systems, coordinate transformations; invariant and frame-dependent quantities; Aristotelian and Galilean spacetime.

Reading: Geroch chs. 1–3

Oct. 20: Newton's bucket

Newton's absolute space; relationalism versus substantivalism about space and spacetime; Newton's bucket experiment; spinning globes; the spacetime structure for classical physics.

Reading: Greene ch. 2

Oct. 24: Leibniz shifts

Static and kinematic Leibniz shift arguments and replies; counting possibilities.

Reading: Huggett, "Leibniz and Clarke: Commentary"; Maudlin, "Buckets of Water and Waves of Space" sec. 3

Oct. 27 Kant's glove

Kant's chirality argument; relationalism and handedness; the tenability of relationalism and substantivalism for classical physics.

Reading: Huggett, "Kant and Handedness: Commentary"

Oct. 31: Midterm 2 in class

Nov. 3: Gunky spacetime

The existence of spacetime points; gunky space; geometry without points.

Reading: Arntzenius, "Pointlessness" secs. 1–3, 6, 13

Nov. 7: Special relativity

Constancy of speed of light; relativity of simultaneity; Lorentz transformations; invariant and frame-dependent quantities; length contraction; car and tunnel.

Reading: Geroch ch. 4; Greene ch. 3 through p. 58; Maudlin, "Relativity and Space-Time Structure"

(*Optional*: Feynman ch. 15)

Nov. 10: Special relativistic spacetime

Minkowski spacetime and the spacetime interval; light cones; time dilation; clock postulate; twin paradox.

Reading: Geroch ch. 5

(*Optional*: Geroch ch. 6; Feynman ch. 17)

Nov. 14: Are all times real?

The metaphysics of time; the reality of the future, past, and present; the question of the compatibility of presentism and special relativity.

Reading: Greene ch. 5; Sider, "Presentism and Special Relativity"

Optional: Hawley, "Science as a Guide to Metaphysics?"

Nov. 17: Does time flow?

The passage of time and special relativity; time in physics versus time in experience; frame-dependent features, frame-independent features, and physical reality; relationship between the manifest and scientific images of the world.

Reading: Ismael and Price, "Stubbornly Persistent Illusions" and Ismael, "Passage, Flow, and the Logic of Temporal Perspectives" secs. 2.6–2.7

Optional: Maudlin, "On the Passing of Time"

Nov. 22: The difference between space and time

Is time different from space, and if so, in what way? Do the laws play a role?

Reading: Skow, "What Makes Time Different from Space?" secs. 1–6

Nov. 28: General relativity

Geometry of curved spaces; gravity as the manifestation of spacetime curvature; the spacetime metric; Einstein's equations.

Reading: Geroch ch. 7

Dec. 1: Midterm 3 in class

Dec. 5: The existence of spacetime in relativity

Relationalism vs. substantivalism in special and general relativity; vacuum solutions; gravitational waves.

Reading: Greene ch. 3, pp. 58–76; Maudlin, "Buckets of Water and Waves of Space" secs. 6–7

Dec. 8: The epistemology of spacetime geometry

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

Reading: Reichenbach, *The Philosophy of Space and Time* secs. 1-4, 8, 12

(*Optional*: Gowers, "Geometry," ch. 6 of *Mathematics: A Very Short Introduction*)

Dec. 12: 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.

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

(*Optional*: Greene ch. 15, pp. 448–455 and 458–469; Lewis, "The Paradoxes of Time Travel")

Take-home final (cumulative) handed out Dec. 12; due Dec. 19.