Philosophy 226: Introduction to Philosophy of Physics

Spring 2020
TF 11:30–12:50, MU 114
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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 (available at the bookstore and on reserve at Alexander library):

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*

Other readings will be available on the Canvas course website

Requirements and Grading

Reading for each class. Required readings will not be very long, but they can be hard. It is recommended that you read through the assignment once before class and again afterward.

Exams: Two in-class midterm exams (each 25% of your final grade) and one in-class final (40% of your final grade).

Attendance and participation: Attendance and participation count for 10% of your final grade. Since exam questions will be based on the material covered in class, poor attendance is likely to lower your grade.

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.

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

Friday 9:30-10:30 am or by appointment, 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. If you miss a class, it is *your responsibility* to get notes and announcements from a classmate.

Jan. 21: Introduction

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

Reading: Greene ch. 1; Loewer, "Philosophy of Physics"; Ruetsche, "Philosophy of Physical Sciences"

Jan. 24: 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:* Feynman ch. 8)

Jan. 28: 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)

Jan. 31: No class

Feb. 4: 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)

Feb. 7: Do 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" (skip sections 2.3 and 5)

(*Optional*: Feynman chs. 13)

Feb. 11: 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, 6; North, "Formulations of Classical Mechanics"

Feb. 14: 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`

Feb. 18: Is Newtonian mechanics time reversal symmetric?

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

Reading: Hutchison, "Is Classical Mechanics Really Time-Reversible and Deterministic?"

(*Optional*: Feynman 14.1–14.4)

Feb. 21: No class

Feb. 25: 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.

Reading: Greene ch. 6; Feynman, "The Distinction of Past and Future"
(*Optional*: Feynman chs. 39, 44, 46)

Feb. 28: A multiverse?

The past hypothesis account of thermodynamics and objections to it. The multiverse and baby universes; Boltzmann brains; explaining initial conditions.

Reading: Carroll, excerpts from *From Eternity to Here*

Mar. 3: MIDTERM EXAM

Mar. 6: 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

Mar. 10: Newton's bucket

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

Reading: Greene ch. 2

Mar. 13: Leibniz shifts

Leibniz shift arguments and replies; counting possibilities.

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

Mar. 24: Kant's glove

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

Reading: Huggett, "Kant and Handedness: Commentary"

Mar. 27: Gunky spacetime

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

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

Mar. 31: Special relativity

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

Reading: Geroch ch. 4; Maudlin, "Relativity and Space-Time Structure"
(*Optional*: Feynman ch. 15)

Apr. 3: Special relativistic spacetime

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

Reading: Geroch chs. 5–6
(*Optional*: Feynman ch. 17)

Apr. 7: The difference between space and time

Is time different from space? If so, in what way are they different?

Reading: Skow, "What Makes Time Different from Space?" (skip sec. 9)

April 10: Are all times real?

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

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

Apr. 14: MIDTERM EXAM

Apr. 17: General relativity

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

Reading: Geroch ch. 7

Apr. 21: No class

Apr. 24: 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

Apr. 28: The epistemology of spacetime geometry

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

Reading: Reichenbach, excerpt from *The Philosophy of Space and Time*

Class 25, May 1: Time travel

The paradoxes of time travel; personal and external time; spacetimes that seem to allow for time travel; the possibility and likelihood of time travel.

Reading: Arntzenius, "Time Travel: Double Your Fun"; Greene ch. 15, pp. 448-469

FINAL EXAM: Date and time TBA

The final exam is cumulative, covering all the material from the semester.

Student wellness services

Just In Case Web App. `http://codu.co/cee05e`. Access helpful mental health information and resources for yourself or a friend in a mental health crisis on your smartphone or tablet and easily contact CAPS or RUPD.

Counseling, ADAP & Psychiatric Services. (848) 932-7884, 17 Senior Street, New Brunswick, NJ 08901, `www.rhscaps.rutgers.edu/`. CAPS is a University mental health support service that includes counseling, alcohol and other drug assistance, and psychiatric services staffed by a team of professional within Rutgers Health services to support students' efforts to succeed at Rutgers University. CAPS offers a variety of services that include: individual therapy, group therapy and workshops, crisis intervention, referral to specialists in the community and consultation and collaboration with campus partners.

Violence Prevention & Victim Assistance. (848) 932-1181, 3 Bartlett Street, New Brunswick, NJ 08901, `www.vpva.rutgers.edu/`. The Office for Violence Prevention and Victim Assistance provides confidential crisis intervention, counseling and advocacy for victims of sexual and relationship violence and stalking to students, staff and faculty. To reach staff during office hours when the university is open or to reach an advocate after hours, call 848-932-1181.

Disability Services. (848) 445-6800, `https://ods.rutgers.edu/`, Lucy Stone Hall, Suite A145, Livingston Campus, 54 Joyce Kilmer Avenue, Piscataway, NJ 08854. Rutgers University welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: `https://ods.rutgers.edu/students/documentation-guidelines`.

If the documentation supports your request for reasonable accommodations, your campus' disability services office will provide you with a Letter of Accommodations. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. To begin this process,

please complete the Registration form on the ODS web site at: https://ods.rutgers.edu/students/registration-form.

Scarlet Listeners. (732) 247-5555, http://www.scarletlisteners.com/. Free and confidential peer counseling and referral hotline, providing a comforting and supportive safe space.