Philosophy 3850/Physics 2202: Philosophy of Physics, Spring 2014
TTh 11:40–12:55, Rockefeller 122
Professor North (north@cornell.edu)
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This course is an introduction to the philosophy of physics. We will discuss issues in the foundations of classical mechanics and relativity, as well as thermodynamics and cosmology, including: Zeno's paradoxes of motion; the existence of instantaneous velocity; the truth of the laws; the question of determinism; the direction of time; the possibility of a multiverse; the difference between space and time; the possibility of time travel; the existence and structure of spacetime. Throughout, we will consider the relationship between physics and philosophy.

Readings

Required books:

Geroch, *General Relativity from A to B*

Greene, *The Fabric of the Cosmos*

Optional book:

Feynman, Leighton, Sands, *The Feynman Lectures on Physics, Volume I*

Other readings are available on the course website (address given out in class)

Requirements and Grading

Reading for each class. Required readings are listed for each class. Optional readings provide extra background or contain more advanced discussions.

Exams. Two in-class midterm exams (each 25% of your final grade) and one in-class final (40% of your final grade). The first midterm exam is in class on March 6. The second midterm exam is in class on April 22. The final exam will be on Tuesday, May 20 at 2:00 pm.

Attendance and participation. Attendance and participation 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 at lectures is mandatory. Lectures will discuss things differently from the readings and will contain additional material. Since exam questions will be based on the material covered in class, poor attendance is sure to lower your grade. Note that if you miss a class, it is *your responsibility* to get notes and announcements from a classmate.

Prerequisites

One philosophy class or one physics class at an advanced high school level (both are recommended). I will assume a minimal familiarity with algebra, geometry, precalculus. One course in calculus is also recommended.

Academic integrity

Each student in this course is expected to abide by the Cornell University Code 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 studying for exams; answers submitted on exams must be your own.

Office Hours

Michelle Wingerter: Monday 11:15am-12:15pm, 344 Goldwin Smith Hall
Professor North: Tuesday 1:00-2:00pm, 235 Goldwin Smith Hall

Schedule

Details are subject to change during the semester. Readings are listed by the date on which they will be discussed. *Note*: there is no class on January 30.

January 23: Introduction

Overview of the class; introduction to philosophy of physics.

Reading: Greene ch. 1 and Ruetsche, "Philosophy of Physical Sciences"

(Optional: Albert, "The Philosophy of Physics"; Feynman chs. 1, 2.1-2; Loewer, "Philosophy of Physics")

January 28: Zeno's paradox

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

Reading: Arntzenius, "Are There Really Instantaneous Velocities?" secs. 1-4 (skip the discussion of time reversibility in sec. 4)

(Optional: J. Carroll, "Instantaneous Motion"; Feynman ch. 8; notes on calculus)

January 30: No class

February 4: Humeanism and the spinning disk

Humeanism in a classical world; neighborhood quantities; intrinsic properties; physical and metaphysical possibility; thought experiments in general and the spinning disk in particular; physics and philosophy.

Reading: Lewis, Introduction to *Philosophical Papers*, *Volume II* and Maudlin, "A Remark on the Method of Metaphysics"

(Optional: Arntzenius, "There Goes the Neighbourhood..." sec. 2.4; Hawley, "Persistence and Non-Supervenient Relations")

February 6: Newtonian mechanics

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

Reading: Albert, "Time-Reversal Invariance"

(Optional: Feynman chs. 4, 7, 9, 10, 11, 52.1-2; notes on vectors and Newtonian dynamics)

February 11: Are the laws of physics true?

Idealizations and approximations in Newtonian mechanics in particular and physics in general; forces, vectors, and components; the existence of component forces; laws and capacities; Humean supervenience.

Reading: Cartwright, "Do the Laws of Physics State the Facts?"

(Optional: J. Carroll, http://plato.stanford.edu/entries/laws-of-nature/; Feynman ch. 12)

February 13: Do Newtonian forces exist?

What can Newtonian physics tell us about the world, given that it is not the true fundamental theory? Newtonian forces; different versions of classical mechanics; realism and instrumentalism; unobservable entities and theoretical posits; Ockham's razor; fundamental theories and special sciences; fundamental and nonfundamental ontology.

Reading: Wilson, "Newtonian Forces" (skip sec. 5)

(Optional: Feynman chs. 13-14; North, "The 'Structure' of Physics: A Case Study")

February 20: Is Newtonian mechanics deterministic?

Space invaders and Norton's dome; time reversal symmetry; idealizations; conservation laws; Newtonian systems.

Reading: Norton, "The Dome: An Unexpectedly Simple Failure of Determinism"

(Optional: Malament, "Norton's Slippery Slope"; Norton, `http://www.pitt.edu/~jdnorton/Goodies/Dome/index.html`)

February 25: Is Newtonian mechanics time reversal symmetric?

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

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

(Optional: Feynman 14.1-4)

February 27: The direction of time

How do we explain the prevalence of temporally asymmetry phenomena in a classical 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

(Optional: Feynman chs. 39, 44, 46)

March 4: A multiverse?

Does the low entropy initial state provide evidence of a multiverse? The past hypothesis account of thermodynamics and objections to it. The multiverse and baby universes; Boltzmann's brains; explaining initial conditions; probabilistic reasoning.

Reading: S. Carroll, "The Past Through Tomorrow" and "Epilogue"

(Optional: Callender, "Measures, Explanations and the Past: Should 'Special' Initial Conditions be Explained?")

March 6: MIDTERM EXAM

You already know the date, so plan ahead: no postponements or excuses. The midterm will be on all the above material. The exam will consist of short-answer questions, each answer a few paragraphs long.

March 11: Classical spacetime

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

Reading: Geroch chs. 1-3

(Optional: Huggett, "Space-Time")

March 13: Newton's bucket

The existence of space and of spacetime in a classical world; the spacetime structure needed for classical physics; spacetime in a classical world; relationalism vs. substantivalism; Newton's bucket experiment; the spinning globes.

Reading: Greene ch. 2

(Optional: Huggett and Hoefer,
`http://plato.stanford.edu/entries/spacetime-theories/`)

March 18: Kant's glove and Leibniz shifts

Kant's chirality argument; Leibniz shift arguments; the tenability of relationalism vs. substantivalism for classical spacetime.

Reading: Huggett, "Kant and Handedness" and Maudlin, "Buckets of Water and Waves of Space: Why Space-Time is Probably a Substance" secs. 1-3

March 20: Gunky spacetime

The structure of spacetime; the existence of spacetime points; "gunky" space; geometry without points.

Reading: Arntzenius, "Pointlessness" secs. 1-3 and 6

(Optional: Arntzenius, "Pointlessness" remaining sections; Arntzenius, "Are There Really Instantaneous Velocities?" sec. 5)

March 25: Special relativity

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

Reading: Geroch ch. 4 and Maudlin, "Relativity and Space-Time Structure"

(Optional: Feynman ch. 15.1-6; Maudlin, "Relativity Theory"; Norton, *Einstein for Everyone*, available at

`http://www.pitt.edu/~jdnorton/teaching/HPS_0410/chapters/index.html`)

March 27: Special relativistic spacetime

Minkowski spacetime; the spacetime interval, light cones; worldlines; proper time; the twin paradox; time dilation; the clock postulate.

Reading: Geroch chs. 5-6

(Optional: Feynman 17.1-3; Luminet, "Time, Topology and the Twin Paradox")

April 8: The difference between space and time

Is time different from space? If so, how do they differ? Does time, unlike space, flow? Time in physics, time in experience.

Reading: Skow, "What Makes Time Different from Space?"

(Optional: Paul, "Temporal Experience"; Sider, "Time")

April 10: Class canceled

April 15: Are all times real?

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

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

(Optional: Putnam, "Time and Physical Geometry")

April 17: General relativity

Gravity as the manifestation of spacetime curvature; geometry on curved surfaces; the metric in general relativity; Einstein's equation.

Reading: Geroch ch. 7 and Maudlin, "Life in Elastic Space-Time" pp. 223-232

(Optional: Geroch ch. 8)

April 22: MIDTERM EXAM

You already know the date, so plan ahead: no postponements or excuses. The midterm will be on all the material since the first midterm. The exam will consist of short-answer questions, each answer a few paragraphs long.

April 24: The existence of spacetime in relativity

Einstein's equation; light cones in curved spacetimes; black holes, gravitational waves; relationalism vs. substantivalism in special and general relativity.

Reading: Greene ch. 3 and Maudlin, "Buckets of Water and Waves of Space: Why Spacetime is Probably a Substance" secs. 5-7

(Optional: Weingard, "On the Ontological Status of the Metric in General Relativity")

April 29: The epistemology of spacetime geometry

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

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

May 1: The hole argument

A new argument against spacetime substantivalism; relationalism and substantivalism in general relativity; diffeomorphism invariance; determinism and indeterminism.

Reading: Earman and Norton, "What Price Space-Time Substantivalism? The Hole Story" (skip sec. 2, but see the "gauge theorem" on p. 520) and Brighouse, "Spacetime and Holes" (skip sec. 3)

(Optional: Norton,
http://plato.stanford.edu/entries/spacetime-holearg/)

May 6: Time travel

The paradoxes of time travel; personal time and external time; free will and the grandfather paradox; spacetimes that allow for time travel; the possibility of time travel; the likelihood of time travel.

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

(Optional: Dyke, "The Metaphysics and Epistemology of Time Travel"; Lewis, "The Paradoxes of Time Travel")

FINAL EXAM: Tuesday, May 20 at 2:00 pm, Rockefeller 102
The final exam is cumulative, covering all the material from the semester.