

Time: Tues. Thurs. 2:30-4
Location: Beckman Institute 121
Office Hours: Tues. Thurs. 4-5

Instructor: Charles T. Sebens
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Office: Dabney 12

COURSE DESCRIPTION

This course will examine the philosophical foundations of the physical theories covered in the freshman physics sequence: classical mechanics, electromagnetism, and special relativity. We will begin with a discussion of the nature and purpose of science to better understand what we can hope to achieve through physics. Then we will study the historical development of Newton's classical mechanics—a theory that was criticized because gravity appeared to involve a strange action-at-a-distance and lacked a local mechanical explanation. Electromagnetism might also seem to involve action-at-a-distance, but this can be avoided if we take the electric and magnetic fields to be real. We will explore in depth the question of whether the fields are real, noting that the fields have been taken to carry energy, momentum, and even mass. We will look at the connection between electromagnetism and the arrow of time, asking whether electromagnetism is a time-symmetric theory and why electromagnetic waves always propagate outwards. We will conclude by studying the transition from electromagnetism—which already contained the seeds of relativity—to Einstein's theory of special relativity. We will focus on the ways in which special relativity unified electricity and magnetism; space and time; and mass and energy.

This course is designed to complement and not overlap (much) the two other philosophy of physics courses offered at Caltech: philosophy of space and time (HPS/Pl 124) and philosophical issues in quantum physics (HPS/Pl 125).

Prerequisite: Ph 1abc (Freshman Physics: Classical Mechanics and Electromagnetism) or instructor's permission.

TEXTBOOK

An Introduction to the Philosophy of Physics: Locality, Fields, Energy, and Mass (2002), Lange

GOALS

- ❖ Gain an appreciation for the variety of ways in which physics and philosophy interact, both in current debates and in the historical development of physical theories.
- ❖ Develop the ability to read and understand difficult texts involving both advanced physics and sophisticated philosophy.
- ❖ Strengthen your understanding of physical theories—in a way that will be useful for applied as well as theoretical purposes—by studying foundational issues.
- ❖ Form educated opinions on philosophical questions at the heart of scientific inquiry (such as “What is a law of nature?” or “How can we tell what’s real?” or “Are all interactions local?”).
- ❖ Acquire the necessary skills to address philosophical problems, so that when you are told a question is “philosophical” you don’t automatically conclude it is unsolvable, not worthy of attention, or beyond your ability to answer.
- ❖ Improve your ability to communicate complex ideas by discussing philosophical questions in class and writing philosophical essays.

ASSIGNMENTS

Problem Sets (30%)

To help you develop the skills necessary to think and write about physics philosophically you will be required to complete four problem sets before submitting your first essay. The questions will require you to engage with reading assignments not yet discussed in class in addition to material already covered. Problem sets are due in class (see schedule) and can be typed or handwritten.

Class Participation (10%)

You are expected to come to every class having done the assigned reading and participate actively in the classroom discussion. A perfect score in participation can be achieved by consistently attending the class, sincerely attempting to understand the material thoroughly, developing the ability to think and debate philosophically, and demonstrating sufficient mastery of the major topics covered in the course. Students who prefer not to speak in class can fulfill this course requirement by coming to office hours and discussing the material there. Two absences will be permitted without penalty. Two of the ten percent will come from completing a full essay draft by 11/5 and participating in the peer review at the Hixon Writing Center.

Essays (60%, 30% each)

You must complete two essays of 1,800-2,500 words each, due in class on 11/12 and 12/1. A typed hard copy must be submitted in class and an electronic copy should be emailed to me before class as well.

SCHEDULE

9/29 **Where Physics Meets Philosophy**

Optional: *Philosophy of Physics* (1992), Chapter 1: Introduction: Philosophy and the Physical Sciences, Sklar (pg. 1-7) [Note page numbers and sections! Sometimes you don't have to read the whole chapter or article.]

10/1 **Theory and Experiment**

Reading: *The Character of Physical Law* (1965), Chapter 7: Seeking New Laws, Feynman (pg. 156-159)
 “What Scientific Idea is Ready for Retirement? Falsifiability” (2014), Carroll www.edge.org/response-detail/25322
 “Scientific Method: Defend the Integrity of Physics” (2014), Ellis and Silk www.nature.com/news/scientific-method-defend-the-integrity-of-physics-1.16535
 Optional: *Theory and Reality* (2003), Chapter 4: Popper: Conjecture and Refutation, Godfrey-Smith

10/6 **What are the Goals of Physics?**

Reading: *An Introduction to the Philosophy of Physics* (2002), Preface, Lange
 Optional: *Language, Truth, and Logic* (1936), Chapter 1: The Elimination of Metaphysics, Ayer
 “Arguments Concerning Scientific Realism” (1980) [selections from *The Scientific Image*], van Fraassen

❖ **First problem set due.** ❖

10/8 **The Development of Classical Mechanics: Aristotle and Galileo**

Reading: *Dialogue on the Two Chief World Systems* (1632), Galilei (selections from the 2nd day)
 Optional: “Aristotle’s Physics: A Physicist’s Look” (2015), Rovelli
Philosophy and the Foundations of Dynamics (2013), Chapter 4: Precursors to Newtonian Dynamics, Section 4.1: Galileo, Sklar

10/13 **Newton’s Classical Mechanics**

Reading: “Newton’s Philosophy” (2014), Sections 1 & 4, Janiak plato.stanford.edu/entries/newton-philosophy/
 Optional: *Philosophical Writings* (2004), Newton, edited by Janiak (pg. xxiii-xxiv, 64-72, 92, 102-103, 106-117; these pages include selections from the *Principia* and Newton’s correspondences with Bentley and Leibniz)

❖ **Second problem set due.** ❖

10/15 **Avoiding Action at a Distance**

Reading: *An Introduction to the Philosophy of Physics* (2002), Chapter 1: What is Spatiotemporal Locality?, Sections 1-4, Lange

10/20 **Fields and Locality**

Reading: *An Introduction to the Philosophy of Physics* (2002), Chapter 2: Fields to the Rescue?, Sections 1-3, Lange

❖ **Third problem set due.** ❖

❖ **First essay prompts distributed.** ❖

10/22 **The Conservation of Energy and Momentum**

Reading: *An Introduction to the Philosophy of Physics* (2002), Chapter 5: Fields, Energy, and Momentum, Sections 1-5, Lange

10/27 **Charting the Flow of Energy**

Reading: *An Introduction to the Philosophy of Physics* (2002), Chapter 5: Fields, Energy, and Momentum, Sections 6-7, Lange

Optional: *The Feynman Lectures on Physics: Volume II* (1964), Chapter 27: Field Energy and Field Momentum, Feynman

Introduction to Electrodynamics (1999), Chapter 8: Conservation Laws, Griffiths (pg. 345-349)

❖**Fourth problem set due.**❖

10/29 **Explaining and Debating Physics in Writing**

11/3 **Time-Reversal Invariance**

Reading: *Time and Chance* (2000), Chapter 1: Time-Reversal Invariance, Albert

Optional: “Transformation Properties of Electromagnetic Quantities under Space Inversion, Time Reversal, and Charge Conjugation” (1973), Rosen

11/5 **Peer Review of Essay Drafts** (at the Hixon Writing Center)

11/10 **Explaining Temporal Asymmetry**

Reading: *Contemporary Debates in Philosophy of Science* (2004), Chapters 11 & 12: Is there a Puzzle about the Low Entropy Past?, Price and Callender, edited by Hitchcock

Optional: *From Eternity to Here* (2010), Chapter 8: Entropy and Disorder, Carroll

The Character of Physical Law (1965), Chapter 5: The Distinction of Past and Future, Feynman (pg. 102-110)

11/12 **The Arrow of Electromagnetic Radiation**

Reading: “Why Things Happen” (2015), Frisch

www.aeon.co/magazine/philosophy/could-we-do-without-cause-and-effect/

Optional: *Introduction to Electrodynamics* (1999), Chapter 10: Potentials and Fields, Griffiths (pg. 416-425)

Time's Arrow and Archimedes' Point (1996), Chapter 3: New Light on the Arrow of Radiation, Price (pg. 49-72, 76-77)

Inconsistency, Asymmetry, and Non-Locality (2005), Frisch (pg. 103-117, 139-142, 152-153)

❖**First essay due.**❖

❖**Second essay prompts distributed.**❖

11/17 **Laws of Nature**

Reading: “Humean Supervenience” (1996), Loewer

Optional: *The Metaphysics Within Physics* (2007), Chapter 1: A Modest Proposal Concerning Laws, Counterfactuals, and Explanations, Maudlin

The Routledge Companion to Philosophy of Science (2014), Chapter 22: Laws of Nature, Lange

11/19 **The Unification of Electricity and Magnetism**

Reading: *An Introduction to the Philosophy of Physics* (2002), Chapter 7: Relativity and the Unification of Electricity and Magnetism, Lange

Optional: “On the Unification of Physics” (1996), Maudlin (pg. 129-133)

11/24 **The Unification of Space and Time**

Reading: *An Introduction to the Philosophy of Physics* (2002), Chapter 8: Relativity, Energy, Mass, and the Reality of Fields, Sections 1-3, Lange

12/1 **The Unification of Mass and Energy**

Reading: *An Introduction to the Philosophy of Physics* (2002), Chapter 8: Relativity, Energy, Mass, and the Reality of Fields, Sections 4-6, Lange

Optional: “Does the Inertia of a Body Depend upon its Energy Content?” (1905), Einstein
Relativity: Special, General, and Cosmological (2006), Chapter 6: Relativistic Particle Mechanics, Rindler

❖**Second essay due.**❖

12/3 **The Big Picture: Questions We’ve Answered and Questions that Remain**

ATTENDANCE AND READING

Engaged participation and careful preparation are important to your success in this course. As there are only about 15 students in the course, I expect everyone to participate regularly in class discussion. Learning to orally examine questions and present your own ideas in a skilled, accurate, professional, and persuasive manner is an invaluable skill in life. By engaging in class discussion you will improve your ability to do this and come to understand the material covered in the course better.

During discussion you will often find yourself disagreeing with other students. When this happens, strive to be respectful. If you can’t understand why someone would believe *that*, then you have something to learn from your interlocutor. The most compelling arguments are offered by those who see the appeal of the other side.

Much of the time you spend learning philosophy will be spent reading and re-reading the texts. Reading philosophy is challenging. I recommend that you re-read confusing parts of the text and take notes, bringing prepared questions with you to class or office hours. The amount of reading varies significantly from day to day, so expect to spend more time on the readings some weeks than others. The readings that are not from the textbook are all available on the course website. Readings should be completed in advance of the class meeting they are associated with.

The optional readings are offered to supplement the required reading. For the most part, you should not need to look at them. However, I advise you to look at them if (a) you’re having difficulty understanding the required reading, (b) you decide to write an essay on that day’s topic, or (c) you happen to find a particular topic especially interesting and would like to read more about it.

LATE ASSIGNMENTS

Homework assignments will be collected at the beginning of class and any late homework assignments must be submitted within 48 hours and will receive a one letter grade deduction. Late essays will receive a one letter grade deduction for each 48 hour period they are late. An extension may be granted if requested in advance of the due date for the assignment. In general, extensions will only be granted for reasons of religious observance, illness, or personal or family emergency. Late assignments should be submitted by email, handed to me in office hours, or brought to my office (provided you email me in advance to ensure I'll be there).

EMAIL

You can reach me at: csebens@gmail.com. Please only email me about logistical concerns: requesting extensions, scheduling additional office hours, etc. I find it is more effective to discuss course content face-to-face. I am happy to meet with you in office hours to discuss any philosophical questions and to schedule additional meetings as needed.

OFFICE HOURS

Office hours are a chance to discuss philosophy with a smaller group of students and a great way to gain knowledge and skills relevant to the course. You may want to stop by to (a) discuss questions about the material covered in the course, (b) talk about other philosophical questions about physics not covered in this course, (c) figure out how to write a philosophical paper or to discuss your plans for a paper, (d) get clarification on the HW problems, or (e) talk about the comments you've received on an essay. I will not read full paper drafts in office hours, but I'm happy to discuss your plan for the paper and talk through a draft or outline with you.

SPECIAL ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES

If you require any special arrangements for completing the course assignments or participating fully in class meetings, please let me know at the beginning of the course.

PLAGIARISM

You are encouraged to discuss your work with other students and even to share drafts with each other to get feedback. However, the work you submit should be your own. If you incorporate the ideas of others, cite those sources. Do not copy language too closely. Even when summarizing and paraphrasing cited sources, you must use your own language and present the ideas in an original way. We will discuss plagiarism further when you are preparing to write your first essay. Please ask me if you have any questions about what counts as plagiarism. More information on plagiarism is available on the Hixon Writing Center's website: www.writing.caltech.edu/students/plagiarism. If I have reason to believe that you have plagiarized, I will report the case to the Board of Control for review. If they determine that it is indeed a case of plagiarism, you will receive a zero on the assignment.