

SAS HONORS SEMINAR: THE DIRECTION OF TIME
F 9:50am–12:50pm
Philosophy department seminar room, 106 Somerset St. 5th floor
J. North (j.north@rutgers.edu)

We will focus on the following problem. How can we explain the temporal asymmetries we experience in everyday life—coffee cools and ice melts, not the reverse; light appears in a room after we flip the switch, not before; we have memories of the past and not the future; we can causally affect the future but not the past—if the underlying laws of physics are symmetric in time, allowing for the time-reversed behavior we never see? Might there be a unified explanation for all these asymmetries? Answering these questions will require looking into the foundations of classical mechanics, statistical mechanics, thermodynamics, electromagnetism, and cosmology. We will also discuss the problem in the context of quantum mechanics.

This problem touches on questions in a variety of areas of philosophy, including philosophy of physics, philosophy of science, and metaphysics. Some of the philosophical issues to be discussed include: What are probabilities in physics? What is a good scientific explanation? What is the relationship between the picture of the world given to us by physics and the one given in ordinary experience? What is the relationship between physics and other sciences? Readings will be drawn from philosophy and physics.

READINGS

Required book, available at the bookstore and on reserve at the Alexander Library undergraduate circulation desk:

David Albert, *Time and Chance*

Optional books (at the bookstore and on reserve at Alexander):

Sean Carroll, *From Eternity to Here*

The Feynman Lectures on Physics, Volume 1

All other readings are available at the course website, address given out in class

PREREQUISITES

A solid high school physics class. Exposure to basic concepts of calculus is helpful, though not required.

Note: this class can be used to count toward the philosophy major or minor.

REQUIREMENTS AND GRADING

Attendance and participation; weekly reading; problem sets. Attendance is mandatory. Note that if you miss a class it is *your responsibility* to get notes and announcements from a classmate. A few problem sets will be given throughout the semester for practice with the physics. These will not involve quantitative reasoning but will focus on physical concepts. Problem sets, participation, and attendance count for 20% of your final grade.

Exams. Two take-home exams consisting of short-essay questions (each answer 1-2 pages; total 5-10 pages). Each exam counts for 40% of your final grade.

Optional readings: I will not assume that you have read these. They provide either further background information or more advanced discussion.

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 questions on problem sets and exams. Problem sets 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 9:00am 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. We may schedule a make-up class at the end of the term.

January 25: INTRODUCTION

Introduction to philosophy of physics and the problem of the direction of time. Symmetry of the fundamental laws, asymmetry of macroscopic phenomena. Asymmetries in the phenomena vs. the asymmetry of time.

Reading: Greene, “Chance and the Arrow” through the middle of p. 8; Price, “The View from Nowhen”

Optional (overviews of issues we will discuss throughout the semester):

Callender, “Thermodynamic Asymmetry in Time,” available at <http://plato.stanford.edu/entries/time-thermo/>; North, “Time in Thermodynamics”

February 1: NO CLASS

February 8: TIME REVERSAL INVARIANCE AND INSTANTANEOUS VELOCITIES

Overview of Newton’s laws of motion and gravitation. Atomic hypothesis; energy conservation; determinism. Symmetries in general and time reversal symmetry in particular. Zeno’s arrow paradox and replies; the existence and definition of instantaneous velocity. What is it for a theory to be symmetric in time? Which theories are time reversal symmetric? What might the time reversal symmetry of a theory tell us about the nature of time itself?

Problem set 1 handed out in class; due in class February 15.

Reading: Albert ch. 1; Arntzenius, “Are There Really Instantaneous Velocities?” secs. 1–4

Optional: Feynman 1.2, chs. 7–10; notes on calculus

February 15: NEWTONIAN DETERMINISM AND TIME REVERSAL SYMMETRY

Is Newtonian mechanics deterministic and time-reversal invariant as ordinarily thought? Arguments that it is not. Space invaders and Norton’s dome; time reversal symmetry; idealizations in physics; Newtonian systems. Friction and dissipative forces; conservation of energy and other conservation laws.

Problem set 1 due in class.

Reading: Hutchison, “Is Classical Mechanics Really Time-Reversible and Deterministic?”; Norton, “The Dome: A Simple Violation of Determinism in Newtonian Mechanics” at <http://pitt.edu/~jdnorton/Goodies/Dome/index.html>

Optional: Feynman chs. 4, 13, 14; Callender, “The Metaphysics of Time Reversal: Hutchison on Classical Mechanics”; Norton, “The Dome: An Unexpectedly Simple Failure of Determinism”

February 22: TIME REVERSAL AND INDETERMINISTIC THEORIES

What it is for an indeterministic theory to be symmetric under time reversal and what does this tell us about the structure of time itself? Is there a difference from the deterministic case?

Reading: Arntzenius, “Indeterminism and the Direction of Time” secs. 1–2 and “Mirrors and the Direction of Time” secs. 1–2

Optional: North, “Two Views on Time Reversal”

March 1 and March 8: THERMODYNAMICS AND STATISTICAL MECHANICS

Overview of thermodynamics and statistical mechanics. The second law of thermodynamics; entropy; Maxwell’s demon; phase space; probability in statistical mechanics. The relationship between thermodynamics and statistical mechanics.

Problem set 2 handed out in class March 1; due in class March 8.

Midterm handed out in class March 8; due in class March 15.

Reading: Albert ch. 2 and ch. 3

Optional: Feynman chs. 39, 44, 46

March 15: THE PAST HYPOTHESIS

Can classical statistical mechanics account for the asymmetry of thermodynamics? The reversibility objections and the past hypothesis. Big bang cosmology; gravity and entropy.

Midterm due in class.

Reading: Albert ch. 4; Feynman, ch. 5 of *The Character of Physical Law*; Greene, “Chance and the Arrow” pp. 8–18

Optional: Price, “‘More Apt to Be Lost than Got’: The Lessons of the Second Law”

March 29: OBJECTIONS TO THE PAST HYPOTHESIS

Objections to the past hypothesis account of thermodynamics. The multiverse and baby universes; Boltzmann brains; explaining initial conditions; probabilistic reasoning.

Problem set 3 handed out in class; due in class April 12.

Reading: Carroll, *From Eternity to Here* excerpts

Optional: Earman, “‘The Past Hypothesis’: Not Even False”

April 5: NO CLASS

April 12: THE WAVE ASYMMETRY

If we drop a pebble in a pond, we see waves ripple outwards to the edge of the pond after we drop the pebble, not before. We see light appear in a room after we flip the switch, not before. In general, waves diverge from their sources; we don't see waves converge on their sources. How can we explain this asymmetry if the laws governing waves are symmetric in time? Is there a similar explanation available to that of the other observed asymmetries?

Problem set 3 due in class.

Reading: Frisch, “(Dis-)Solving the Puzzle of the Arrow of Radiation” sec. 5; North, “Understanding the Time-Asymmetry of Radiation”

Optional: Feynman chs. 28–29; “A Tale of Two Arrows”

April 19: QUANTUM MECHANICS

Does quantum mechanics make a difference to the explanation of thermodynamics? Overview of quantum mechanics and Albert's argument that it does.

Problem set 4 handed out in class; due in class April 26.

Reading: Albert ch. 7

Optional: Price, “Boltzmann's Time Bomb”; North, “What is the Problem about the Time-Asymmetry of Thermodynamics?—A Reply to Price”

April 26: THE ASYMMETRIES OF KNOWLEDGE AND INTERVENTION

If I were to do something different now, the future, but not the past, would be different. How can we explain the fact that the future counterfactually depends on the past, and not vice versa? How can we explain the fact that we have knowledge of the past and not the future, and that we can generally affect things in the future but not the past? Can we account for these in a similar way to the other asymmetries? Can Albert's version of statistical mechanics explain all of the macroscopic asymmetries we have considered?

Problem set 4 due in class.

Reading: Albert ch. 6

Optional: Lewis, “Counterfactual Dependence and Time's Arrow” with postscripts; Elga, “Statistical Mechanics and the Asymmetry of Counterfactual Dependence”; Albert, “The Difference between the Past and the Future”

May 3: TIME TRAVEL

Final exam handed out in class. Due by email by 12pm noon, May 15.

Paradoxes of time travel; personal time and external time; the grandfather paradox; time travel and free will; backwards causation; the possibility of time travel and the likelihood of time travel.

Reading: Lewis, “The Paradoxes of Time Travel”; Dyke, “The Metaphysics and Epistemology of Time Travel”

Optional: Arntzenius, “Time Travel: Double Your Fun”

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.