ARLT-100: Einstein's Spacetime Revolution

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Course Website: https://blackboard.usc.edu
Prerequisites: none

Semester: Fall 2012
Section: tba
Class Time: tba
Room: tba
Units: 4

Course Description

Is it possible to slow down how fast you age? Is the force of gravity an illusion? Can the Universe have an edge? Is there a beginning of time? Is time travel possible? Amazingly, the answer to all of these questions is *yes*, according to Einstein's revolutionary theories of relativity. This class will provide an overview of how these theories revolutionized the way we understand space, time and gravity, allowing students to engage in the many philosophical puzzles that accompanied these changes.

Students will undertake a detailed philosophical and conceptual analysis of texts by Einstein himself, as well as by philosopher of space and time John D. Norton. We begin with an introduction to the central principles of special relativity, and how it requires the concept of "simultaneous events" to be relative. We analyze some apparent paradoxes commonly associated with these ideas, and some philosophical consequence for the nature of time and for cause and effect. We then turn to general relativity, the geometry it suggests for space and time, and its revolutionary consequences for the nature of cosmology, determinism, and the passage of time.

This course requires absolutely no background in physics or math. Indeed, students will only need to learn two equations, which really cannot be omitted: $E = mc^2$, and Einstein's equation!

Course Objectives

Philosophers and other non-scientists often make claims of the form, "We know that such and such, because of Einstein's theories." This course will equip non-scientists with the conceptual and argumentative background needed to evaluate such claims. Students will learn the techniques of good philosophical analysis and argument, and apply those techniques to philosophical puzzles surrounding Einstein's theories of relativity. Through intensive reading and writing assignments based on primary texts, students will critically analyze the paradigm shift brought on by these theories, while evaluating the consequences for the philosophy of science.

Textbooks

[1] Einstein, Albert (1920). *Relativity: The special and general theory*. New York: Henry Holt and Co. Available as a free eBook through Google Books, among other places.

[2] Euclid (1908). *The Thirteen Books of Euclid's Elements*, Volume I, T. L. Heath (Trans.), Cambridge: Cambridge University Press. Available as a free eBook through Google Books, among other places.

[3] Norton, John D. (2007). *Einstein for Everyone*. Nullharbor Press. Available as a free eBook through http://www.pitt.edu/~jdnorton/teaching/HPS_0410/chapters/index.html.

[4] Poincaré, Henri (1905). *Science and Hypothesis*. New York: The Science Press. Available as a free eBook through Google Books, among other places.

Course Requirements

Students will be evaluated on the basis of weekly reading questions (10%), 2 essays (40%), a midterm (20%), and a final exam (30%).

a. Weekly readings

This class is reading intensive; all the course textbooks will be covered almost in their entirety, in addition to some additional related articles. Each class session is also associated with a set of reading questions. Please answer them as completely and concisely as you can. (If an answer only requires one sentence, only use one sentence!) Your answers to both question sets for a given week will be due on the Friday after they were assigned, before noon. These answers must be submitted online through Blackboard. Of the 24 assigned question sets, you are only required to submit 20. For this reason, *no late reading questions will be accepted.*

b. Essays

You will be given 2 essay prompts over the course of the term. These essays should be 1500-2000 words long, and are due before the hour of the midterm and final exams, respectively. The first essay will deal with a philosophical problem arising from special relativity; the second will deal with one arising from general relativity. Each paper should include the following.

1. *A 1-2 sentence thesis in response to the essay prompt.* Your thesis should be short, specific, and must answer the prompt.
2. *A discussion of the relevant scientific background.* You may draw on material introduced in class and in the readings for this part. Proceed as if you are describing the material for your grandmother; you should not assume the reader has any background knowledge about the material.
3. *A valid argument in support of your thesis.* This is the most important part. Your argument should state clear and plausible premises, which logically imply your conclusion. You may support these premises using material from class, or using other material, so long as it is from an appropriate scholarly source. (Wikipedia is not one.)

Ten percent of each essay grade (2 out of 20 points) will be satisfied by turning in a "preliminary sketch" one week before the paper is due. This sketch must contain a statement of the thesis you expect to argue, together with a short (3-5 sentence) discussion of the points that you are considering incorporating into your argument. Both this sketch and the essay itself must be submitted online through http://Turnitin.com.

A philosophy essay *is different than other academic papers.* If you have not written one before, never fear! We will be discussing what is required in class. For starters, please read and follow the guidelines set out in my 7 Steps to a Better Philosophy Paper.

c. Midterm and final exams

The midterm will take place in Week 7. The final exam will be on the scheduled final exam day for this class. Both the midterm and the final will be cumulative, covering material from readings, lectures, and assignments.

Course Schedule

1. Special Relativity

Week 1. Overview

1.1 Introduction to Einstein's revolution. (Norton Chapter 1, Einstein I-IV, Poincare Part I.)

1.2 Introduction to Special Relativity (Norton Chapter 2, Einstein V-VII)

Week 2. The structure of special relativity

2.1 Adding velocities at relativistic speeds (Norton Chapter 3, Einstein V-VI, Poincare Part II.)

2.2 The relativity of simultaneity (Norton Chapter 4, Chapter 5)

Week 3. Mass, energy and momentum

3.1 $E = mc^2$ (Norton Chapter 6, Einstein XV, Poincare Part III.)

3.2 Spacetime (Norton Chapter 9, Chapter 10)

Week 4. Philosophical foundations of special relativity

4.1 Origins of special relativity (Norton Chapter 7, Einstein XIII, Poincare Part IV.)

4.2 How to visualize higher-dimensional spaces (Norton Chapter 12, Einstein XVII)

Week 5. Philosophical problems in special relativity

5.1 Spacetime, tachyons, twins and clocks (Norton Chapter 11)

5.2 Time, causation, and other concerns (Norton Chapter 13)

2. General Relativity

Week 6. Geometry of space and time

6.1 Euclidean geometry (Norton Chapter 14, Einstein XX-XXI, Euclid Book I)

6.2 Non-Euclidean geometry (Norton Chapter 15, Einstein XXIV, Euclid Book II)

Week 7. Curvature and geodesic deviation

7.1 Constant and variable curvature (Norton Chapter 16)

7.2 Intrinsic, extrinsic curvature (Norton Chapter 17)

Week 8. The basics of General Relativity

8.1 Gravity and curvature (Norton Chapter 18, Einstein XXII)

8.2 How planets bend space and time (Norton Chapter 19)

Week 9. Cosmology

9.1 Cosmology (Norton Chapter 21, Einstein XXX-XXXI)

9.2 Big bangs and the beginning of time (Norton Chapter 22)

Week 10. Black Holes

10.1 Black holes (Norton Chapter 23)

10.2 Wormholes and Penrose Diagrams (Norton Chapter 24)

3. More philosophical puzzles

Week 11. Time travel in relativity theory

11.1 Time travel spacetimes (Maudlin & Artzenius, SEP: Time Travel in Modern Physics)

11.2 Observationally indistinguishable spacetimes (Norton, " Observationally Indistinguishable Spacetimes: A Challenge for Any Inductivist")

Week 12. Determinism and Substantivalism

12.1 Space evaders and space invaders (Hoefer SEP: Causal Determinism)

13.1 Substantivalism, relationism, and the hole argument (Norton SEP: The Hole Argument)

Week 13. Einstein's pathway to relativity

13.2 Einstein's pathway to special relativity (Norton Chapter 8)

13.3 Einstein's pathway to general relativity (Norton Chapter 20, Einstein XXIII)

Week 14. Holes in Spacetime

14.1 Notes on Holes (Bryan's Notes on Holes)

14.2 Final exam review

Policy on late coursework

No late reading assignments will be accepted, since you are only required to turn in 20 of the 24 question sets. If you accidentally sleep in, are called out of town, or have a sick dog – I understand! That's what the freebees are there for. Late essays and exams are not allowed; in extreme cases, you may contact me about scheduling them early.

How to do well in this course

This course is about some of the most amazing ideas ever imagined by human beings. They are also well within your capacity to digest and analyze. However, they are not easy. Come to class having studied the readings as best you can, take notes in class, and then review the material again when you go home. Discuss the material with your classmates. Make sure you ask about any reading questions you can't answer. You are very, very welcome to get in touch with me to discuss difficulties when you run into them. I am available in office hours, and will typically respond to email within 1 work day. Remember, philosophy takes some time to process. That is normal. The more time you give yourself, the more likely you'll be to succeed.

Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. SCampus, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A, http://scampus.usc.edu/university-student-conduct-code/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at http://www.usc.edu/student-affairs/SJACS/.

Disability Services

Students with special needs are warmly encouraged to contact me about accommodations. Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me as early in the semester as possible. DSP is located in the Student Union (STU) room 301 and is open 8:30 am - 5:00 pm, Monday through Friday, and may be contacted by phone at (213) 740-0776.