

Physics/Philosophy 419/420: Space, Time and Matter, Fall 2012

Time: Tues. Thurs. 2:00 – 3:20 p.m.

Place: 144 Loomis Laboratory

	Name	Office	Office Hour	E-mail
Instructor	A.J. Leggett	2113 ESB	Mon. 4:00	aleggett@illinois.edu
TA	K. Decker	390N Loomis	Tues 4:00 (or by appointment)	kdecker4@illinois.edu
TA	C Byrne	Off Campus		bcharles@illinois.edu
TA	V. Crecea	Off Campus		crecea@illinois.edu

Discussion Class: Thurs. 4:00 Room 158 Loomis (next to lecture room)

Approximate Syllabus and Schedule

The Aristotelian-Ptolemaic picture of the Universe and Copernican revolution: the birth of modern mechanics and the philosophical problems raised by it.

The theory of electromagnetism and the ether: conflict between electrodynamics and mechanics. The special theory of relativity and its paradoxes. Mach's principle and general relativity: philosophical implications.

Basic ideas of quantum mechanics. Bell's theorem and the issue of locality in physics. The quantum measurement problem and attempts to modify the theory. The implications of quantum mechanics for the notion of "objective reality".

Irreversibility and the "direction of time": current problems in cosmology. Philosophical wrap-up.

Lecture 1	Tues. 28 Aug	General introduction: what is philosophy of physics? A taste of things to come. (Sklar, §1, Cushing, part I, Rohrlich, §§1-3)
Lecture 2	Thurs. 30 Aug	The Aristotelian-Ptolemaic world view. (Cushing, §4, Kuhn, §§1-4, Koestler, parts I-II, Geroch, §1)
Lecture 3	Tues. 4 Sept	The work of Copernicus. (Cushing, §4, Kuhn, §5, Koestler, part III)
Lecture 4	Thurs. 6 Sept	The sequel to Copernicus and the work of Kepler. (Cushing, §5, Kuhn, §6, Koestler, part IV)
Lecture 5	Tues. 11 Sept	Galileo and the birth of modern mechanics. (Cushing, §6, Koestler, part V, Feynman, §4)
Lecture 6	Thurs. 13 Sept	The Newtonian synthesis. (Cushing, §§7 and 8, Feynman §§1-4, Rohrlich, §5)
Lecture 7	Tues. 18 Sept	Philosophical problems of Newtonian mechanics. (Cushing, part IV, Sklar, pp 11-25, Rohrlich, §5, Hesse, §6)
Lecture 8	Thurs. 20 Sept	Invariance and conservation laws. (Feynman, §§3 and 4, Rohrlich, §6)
Lecture 9	Tues. 25 Sept	Waves. (Rohrlich, §10a, Herbert, §5)
Lecture 10	Thurs. 27 Sept	Electricity, magnetism and the propagation of light. (Cushing, §§13 and 14, Rohrlich, §6a, Einstein, app. 5)
Lecture 11	Tues. 2 Oct	Space, time and simultaneity: foundations of special relativity. (Einstein, §§I - XI, Rohrlich, §6, Sklar, pp 25-40, Geroch, §§5 and 6)
Lecture 12	Thurs. 4 Oct	Paradoxes of special relativity. (Cushing, §17, Einstein, §§XII-XVII)
Lecture 13	Tues. 9 Oct	Mechanics of special relativity: the mass-energy relation. (Cushing, §17, Rohrlich, §6f)
Lecture 14*	Thurs. 11 Oct	General relativity: equivalence principle and space-time curvature. (Cushing, §18, Rohrlich, §6, Sklar, pp 40-52, Geroch, §7, Sciama)

*Will probably be given by video conference

Lecture 15	Tues. 16 Oct	Philosophical questions raised by special and general relativity. (Sklar, pp 53-91)
Lecture 16	Thurs. 18 Oct	“Wave-particle duality”: the basic experimental facts. (Cushing, §19, Rohrlich, pp 119-144, Sklar, pp 157-164, Herbert, §§1-5)
Lecture 17	Tues. 23 Oct	Wave-particle duality and 2-slit experiment: analysis. (Cushing, §20, Feynman, §6, Rohrlich, pp 144-166, Sklar, pp 164-179, d’Espagnat, §3, Albert, §§1 and 2)
Lecture 18	Thurs. 25 Oct	Determinism, probability and objectivity in classical and quantum physics. (Sklar, pp 92-108, d’Espagnat §§5 and 6)
Lecture 19	Tues. 30 Oct	Hidden variables. (Sklar, pp 202-212, Herbert, §7)
Lecture 20	Thurs. 1 Nov	The EPR argument and Bell’s theorem. (Cushing, §22, Sklar, pp 213-226, d’Espagnat, §§4 and 7, Herbert, §8, Albert, §§4 and 5)
Lecture 21	Tues. 6 Nov	The quantum measurement paradox: the “orthodox” solution. (Sklar, pp 179-193, Herbert, §8, Albert, §4 and 5)
Lecture 22	Thurs. 8 Nov	The quantum measurement paradox: alternative solutions and experimental tests. (Sklar, pp 193-202, Herbert, §§9 and 10, Albert, §§6-8)
Lecture 23	Tues. 13 Nov	Quantum mechanics and “reality”: overview. (d’Espagnat, §§8 -12, Herbert, §13)
Lecture 24	Thurs. 15 Nov	The advantages of ignorance: statistical mechanics. (Sklar, pp 109-142, Reichenbach, pp 49-108)

Thanksgiving Break – No Classes – November 20 & 22

Lecture 25	Tues. 27 Nov	The arrow of time. (Sklar, pp 142-156, Hawking, §9, Reichenbach pp 1-45 and 103-205)
Lecture 26	Thurs. 29 Nov	Cosmology: the standard model. (Hawking, §§1-3)
Lecture 27	Tues. 4 Dec	Philosophical issues in cosmology. (Hawking §§8-11)
Lecture 28	Thurs. 6 Dec	What have we learned? (Sklar, §5)
Lecture 29	Tues. 11 Dec	The current situation in physics: a personal overview.

Reading

No single text covers the entire course; from lecture 6 onwards I hope to get typed lecture notes out in advance. Other recommended reading:

A) General

- 1.§ L. Sklar, “Philosophy of Physics,” (Westview Press, Boulder, CO, 1992). This covers a large fraction of the material and is nearest to a course text. It is somewhat densely argued and you must be prepared if necessary to read any particular passage several times.
- 2.§ J.T. Cushing, “Philosophical Concepts in Physics” (Cambridge University Press, 1998). Somewhat similar in coverage to Sklar, but more historically oriented. Cushing has a definite thesis to advocate, see in particular the part on quantum mechanics, but this does not detract from the usefulness of the text.

§Listed as “required alternatives” for bookstore and library purposes.

- 3.§ F. Rohrlich, "From Paradox to Reality: Our Basic Concepts of the Physical World," (Cambridge University Press, Cambridge, MA 1987). While in my opinion historically and philosophically naive, this book complements Sklar by presenting an attitude towards the fundamentals which is probably typical of that of many thoughtful working physicists.
4. R.P. Feynman, "The Character of Physical Law," (MIT Press, 1993). The famous Messenger lectures by one of the leading physicists of the twentieth century: covers a few topics with extreme lucidity.
5. A.J. Leggett, "The Problems of Physics," (Oxford University Press, Oxford, UK, 1987) May be of interest as expressing, particularly in chapter 5, the lecturer's personal views on some of the more controversial topics!

B) Particular Topics:

The Copernican - Newtonian Revolution:

6. T.S. Kuhn, "The Copernican Revolution," (MIT Press, 1957). A scholarly examination of the earlier part of the "scientific revolution" of the 16th and 17th centuries, by a leading historian of science.
7. A. Koestler, "The Sleepwalkers," (Macmillan, London, UK, 1959). A lively nontechnical history (with some elements of the gossip column!) of the genesis and earlier part of the revolution. Its considerable length is more than compensated by its readability, but you should beware of the odd error in physics as well as, possibly, in the history.
8. Mary B. Hesse, "Forces and Fields," (Greenwood Press, Westport, CT, 1970). Traces the history of the concept of action at a distance from the Greeks to modern quantum field theory, with a substantial section on Newton. May be rather dense going for some.

Special and General Relativity:

9. A. Einstein, "Relativity, the Special and General Theory," (Crown Trade Paperbacks, NY, 1961).
10. D.W. Sciama, "The Physical Foundations of General Relativity," (Doubleday, Gordon City, 1969).

These books are fairly easy to read but nevertheless get to grips with the essential conceptual innovations made by the theory of relativity.

11. R. Geroch, "General Relativity from A to B," (University of Chicago Press, Chicago, 1978). Recommended for those non-physics majors who want to go into the structure of general relativity a little more deeply. (As the author eschews even the most elementary algebra, physics majors are likely to find the pace irritatingly slow).
12. C.M. Will, "Was Einstein Right?" (Basic Books, New York, 1993). A nontechnical and very readable account of the experimental status of general relativity in the 90's.
13. S.W. Hawking, "A Brief History of Time," (Bantam Books, NY, 1988). A popular account of some of the more intriguing recent ideas in cosmology. (Warning: the experimental evidence for many of these is currently nonexistent!)

§Listed as "required alternatives" for bookstore and library purposes.

Quantum Mechanics†

14. N. Herbert, “Quantum Reality,” (Anchor/Doubleday, Gordon City, 1985). Probably the best available non-technical discussion of the paradoxes of quantum mechanics for the general reader.
15. G.J. Milburn, “The Feynman Processor: Quantum Entanglement and the Computing Revolution”. (Helix Books (Perseus Books), Reading, Mass, 1998). A somewhat breathless popular-level approach to the foundations of quantum mechanics, motivated by the exploding field of quantum computing.
16. D.Z. Albert, “Quantum Mechanics and Experience,” (Harvard University Press, Cambridge, MA, 1992). Covers most currently advertised approaches to the quantum measurement problem: while ostensibly written for the general reader, it demands a certain amount of mathematical effort.
17. B. d’Espagnat, “In Search of Reality,” (Springer-Verlag, New York, 1983). An attempt by a leading physicist to draw out the implications of Bell’s theorem for philosophy.

The “Arrow of Time”

- 18.‡ H. Reichenbach, “The Direction of Time,” (University of California Press, Berkeley, CA, 1956) A classic discussion by a leading member of the logical empiricist school.
19. H. Price, “Time’s Arrow and Archimedes’s Point: new directions for the physics of time.” (Oxford University Press, New York, 1996). A very thoughtful and densely argued approach to the question of time asymmetry: particularly good on the cosmological aspect of the problem.

Assessment††

The grades will be based on a final exam (25%), a term paper (50%) and several short written exercises (25%). The final exam will be closed-book and will consist of several brief essay questions. There will be four to six short written exercises at various points throughout the course, the first being due on Thursday, Sept. 13, 2012. An *outline* of the term paper will be due on Oct. 18, the first complete draft on Nov. 15, and the final revised version on Dec. 11: see “Notes on the Term Paper”. The final exam is on Fri, Dec 14, from 7:00 to 10:00 p.m. This course is accredited for “Composition II” status, and there will be “feedback” sessions arranged for both the short written exercises and the term paper. All written work must be submitted via the Compass system: see instructions on course website. Policy on work submitted late: automatic deduction of 10% per day late.

†An approximate order of increasing difficulty among the texts cited for quantum mechanics is Feynman, Milburn, Herbert, Rohrlich, de’Espagnat, Sklar, Albert. The last is not essential reading but is recommended for those who want to get a more quantitative feeling for the subject.

‡ Reichenbach is likely to be fairly tough going for those who have not met the subject-matter before in a more technical context.

†† The notes on the term paper apply to Physics/Philosophy 419 only. The assessment of Physics/ Philosophy 420 is based on a final exam and short written exercises only (50% each).