Space Time and Matter 419/420, Fall 2010

Time: M W 2:30 – 3:50 p.m.
Place: 144 Loomis Laboratory

	Name	Office	Office Hour	E-mail
Instructor	A.J. Leggett	2113 ESB	Tuesday 3 p.m.	aleggett@illinois.edu
TA	Charles Byrne	2128 ESB	Th. 12-1:00p.m.	bcharles@illinois.edu
TA	Vasilica Crecea	2128 ESB	Th. 5-6:00 p.m.	crecea@illinois.edu

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	Mon. Aug 23	General introduction: what is philosophy of physics? A taste of things to come. (Sklar, §1, Cushing, part I, Rohrlich, §§1-3)
Lecture 2	Wed Aug 25	The Aristotelian-Ptolemaic world view. (Cushing, §4, Kuhn, §§1-4, Koestler, parts I-II, Geroch, §1)
Lecture 3	Mon Aug 30	The work of Copernicus. (Cushing, §4, Kuhn, §5, Koestler, part III
Lecture 4	Wed. Sept 1	The sequel to Copernicus and the work of Kepler. (Cushing, §5, Kuhn, §6, Koestler, part IV)

Labor Day –no class Mon. Sept. 6

Lecture 5	Wed. Sept 8	Galileo and the birth of modern mechanics. (Cushing, §6, Koestler, part V, Feynman, §4)
Lecture 6	Mon. Sept 13	The Newtonian synthesis. (Cushing, §§7 and 8, Feynman §§1-4, Rohrlich, §5)
Lecture 7	Wed. Sept 15	Philosophical problems of Newtonian mechanics. (Cushing, part IV, Sklar, pp 11-25, Rohrlich, §5, Hesse, §6)
Lecture 8	Mon. Sept 20	Invariance and conservation laws. (Feynman, §§3 and 4, Rohrlich, §6)
Lecture 9	Wed. Sept 22	Waves. (Rohrlich, §10a, Herbert, §5)
Lecture 10	Mon. Sept 27	Electricity, magnetism and the propagation of light. (Cushing, §§13 and 14, Rohrlich, §6a, Einstein, app. 5)
Lecture 11	Wed. Sept 29	Space, time and simultaneity: foundations of special relativity. (Einstein, §§I - XI, Rohrlich, §6, Sklar, pp 25-40, Geroch, §§5 and 6)
Lecture 12	Mon. Oct 4	Paradoxes of special relativity. (Cushing, §17, Einstein, §§XII-XVII)
Lecture 13	Wed. Oct 6	Mechanics of special relativity: the mass-energy relation. (Cushing, §17, Rohrlich, §6f)
Lecture 14	Mon. Oct 11	General relativity: equivalence principle and space-time curvature. (Cushing, §18, Rohrlich, §6, Sklar, pp 40-52, Geroch, §7, Sciama)
Lecture 15	Wed. Oct 13	Philosophical questions raised by special and general relativity. (Sklar, pp 53-91)

Lecture 16	Mon. Oct 18	“Wave-particle duality”: the basic experimental facts. (Cushing, §19, Rohrlich, pp 119-144, Sklar, pp 157-164, Herbert, §§1-5)
Lecture 17	Wed. Oct 20	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	Mon. Oct 25	Determinism, probability and objectivity in classical and quantum physics. (Sklar, pp 92-108, d’Espagnat §§5 and6)
Lecture 19	Wed. Oct 27	Hidden variables. (Sklar, pp 202-212, Herbert, §7)
Lecture 20	Mon. Nov 1	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	Wed. Nov 3	The quantum measurement paradox: the “orthodox” solution. (Sklar, pp 179-193, Herbert, §8, Albert, §4 and 5)
Lecture 22	Mon. Nov 8	The quantum measurement paradox: alternative solutions and experimental tests. (Sklar, pp 193-202, Herbert, §§9 and 10, Albert, §§6-8)
Lecture 23	Wed. Nov 10	Quantum mechanics and “reality”: overview. (d’Espagnat, §§8 -12, Herbert, §13)
Lecture 24	Mon. Nov 15	The advantages of ignorance: statistical mechanics. (Sklar, pp 109-142, Reichenbach, pp 49-108)
Lecture 25	Wed. Nov 17	The arrow of time. (Sklar, pp 142-156, Hawking, §9, Reichenbach pp 1-45 and 103-205)

Thanksgiving Break – No Classes – November 22 & 24

Lecture 26	Mon. Nov 29	Cosmology: the standard model. (Hawking, §§1-3)
Lecture 27	Wed. Dec 1	Philosophical issues in cosmology. (Hawking §§8-11)
Lecture 28	Mon. Dec 6	What have we learned? (Sklar, §5)
Lecture 29	Wed. Dec. 8	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.

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.

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

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!)

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 three or four short written exercises at various points throughout the course, the first being due on Thursday, Sept 9, 2010. An *outline* of the term paper will be due on Oct 21, the first complete draft on Nov 18, and the final revised version on Dec 9. The final exam is on Fri Dec 17, from 1.30 to 4.30 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.

†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 above notes on assessment apply to Physics 419 only. Students taking Physics 420 do not write a term paper and are assessed on the short written exercises (50%) and the final examination (50%).