

Physics 107	20th Century Concepts of Space, Time and Matter
Prof. P. Berman	Fall, 2009

Welcome to 20th Century Concepts of Space, Time and Matter. This course is intended to provide you with a picture of space, time and matter, as interpreted by physicists. The course will be divided roughly into two sections. The first deals with Special and General Relativity and the structure of space-time. The second half is concerned with the quantum theory and the structure of matter. The required books for the course are:

Einstein and Infeld - *The Evolution of Physics* (Ulrich's)
Hoffmann - *Relativity and its Roots* (Ulrich's)
Gribben - *In Search of Schrodinger's Cat* (Ulrich's)
Oerter - *The Theory of Almost Everything* (Ulrich's)

Recommended but not required

Davies - *Space and Time in the Modern Universe* (out of print)*
Gamow - *Biography of Physics, Thirty Years that Shook Physics* (out of print)
Eddington - *Space, Time and Gravitation**
Bergmann - *The Riddle of Gravitation*
Einstein - *Relativity**
P.C.W. Davies - *The Forces of Nature**
R. K. Adair - *The Great Design**
P.C.W. Davies - *The Edge of Infinity*
F. Rohrlich - *From Paradox to Reality*
Trefil - *From Atoms to Quarks** (out of print)

(* On reserve at Shapiro)

Unfortunately, there is no single text that is suitable for the course. The required texts will be supplemented with hand-out material.

This course is intended as an introduction to concepts in physics. Please feel free to ask questions as we go along. I hope that the class atmosphere is relaxed enough to permit you to ask questions when you don't understand what has been said or if some foreign term was used. Also, to get the most out of this course, *class attendance is very important* since there is no one text that is followed. The major goal of this course is to leave you with a sense that a general knowledge of physics can be gained without any *advanced* mathematical background and to encourage you to continue to broaden your scientific knowledge. I welcome your suggestions for ways in which the course may be improved.

A supplementary reading list will be distributed.

Your responsibility in the course is to do the readings and the assigned problems. There will be two mid-term and a final examination in the course. Your grade will be determined as follows:

midterm exams $2 \times 1/5 = 2/5$
final exam $2/5$
homework $1/5$

There is an optional project to be described on another sheet.

All problem assignments, course hand-outs, and announcements will be posted on CTOOLS.

My office hours will be Tuesday, Thursday, 3:00 — 4:00, or by appointment, in Room 4227 of the new Randall laboratories. I can be reached on email at pberman@umich.edu. If there is sufficient interest, an optional recitation section will be held on Thursdays from 4:00-5:00 in Room 4404 Randall. Please see me to discuss problems you are having with the course or to discuss any of the subject matter in greater depth.

Math required for this course

You are expected to know elementary algebra and geometry for this course. Some knowledge of trigonometric functions would also be helpful, but will be taught in the course. You should be able to use a scientific calculator. The homework will require some mathematical calculations as will the exams. Quantitative reasoning involving both mathematical and deductive arguments will be stressed throughout the course. The exams will always have sufficient choice to enable you to demonstrate your understanding of the course material, even if mathematics is not your strong point.

At the end of this course, some students always complain that the math was too hard or the level too high (whatever “too high” means) for a “100” level course that is designed to be accessible to nonscience majors. The diversity of students in this course is significant and I try to teach at a level that is stimulating to as large a proportion of students as is possible. Some degree of abstract thinking is a necessity for understanding the course material. This is *not* a course in memorization of a number of facts. One goal of the course is to help you develop your powers of abstract thinking. If you have any questions about the mathematical level of the course, please see me as soon as possible.

Course Outline

Texts: Einstein and Infeld — “Evolution of Physics” (*E*)
Hoffmann -- “Relativity and its Roots”..... (*H*)
Gribben — “In Search of Schrodinger’s Cat” (*G*)
Oerter — “The Theory of Almost Everything” (*O*)

I. Galilean Relativity, Newton’s Laws of Motion, Concepts of force, inertial mass, gravitational mass.

(3 weeks) (*E*) 1-47, (*H*) Chaps. 1-3, plus class notes.

- II. Field concept: Gravitational fields, Electric and Magnetic fields, Ether
(1 lecture) (E) 69-122, (H) Chap 4.
- III. Special theory of relativity. Concepts of absolute versus relative quantities. Simultaneity, length, and time intervals as relative concepts. Twin paradox, space-time diagrams — interdependence of space and time.
(2½ weeks) (E) 125-208 (H) Chap. 5 (Chap. 3 - optional), plus class notes.
- IV. General theory of relativity. Principle of equivalence, reinterpretation of equivalence of inertial and gravitational mass. Geometry of space-time and its dependence on matter. Models of Universe, Black Holes.
(1½ weeks) (E) 209-245. (H) Chap. 6.
- V. Transverse and longitudinal waves. Electromagnetic spectrum. Standing waves. Superposition and interference.
(2 lectures).(E) 105-119, 273-276, (G) Chap. 1, (O) Chaps. 1 and 2, plus class notes
- VI. Origins of the quantum theory. Work and Energy. Blackbody radiation and the “ultraviolet catastrophe.” Photoelectric effect. Bohr theory of the hydrogen atom.
(4 lectures). (E) 249-270 (G) Chaps. 2,3,4 (O) Chaps. 2 and 3, plus class notes.
- VII. DeBroglie waves. Schrodinger’s equation. Probability interpretation of the wave function. Heisenberg uncertainty principle. Return to the hydrogen atom — quantum numbers. Angular momentum and symmetry. Spin, Pauli exclusion principle, periodic chart
(6 lectures). (E) 270-297 (G) Chaps. 5-8 (O) Chaps. 3 and 4, plus class notes.
- VIII. EPR Paradox, Bell’s Inequalities.
(1 lecture). (G) Chaps. 9-11, plus class notes
- IX. The Standard Model of Elementary Particle Physics. Symmetry and degeneracy. Classification of particles. Quark Model of the Baryons. Leptons. Unified theories of the fundamental forces. String theory.
(5 lectures). (O) Chaps. 5-12 and Appendix A, plus class notes.

Units

In calculations, one must use a consistent set of units. In this course, we will use both the MKS (meter, kilogram, second) and British systems. Some units and conversion factors are given below. Note: in any formula, you must use the same “system” for each variable which appears — you can’t mix feet and kg, for example.

Physical Quantity	MKS	British
Length	m (meter)	ft. (foot)
Time	s (second)	s (second)
Mass	kg (kilogram)	slug
Volume	m ³ (cubic meter)	ft ³ (cubic foot)
Speed	m/s	ft/s
Acceleration	m/s ²	ft/s ²
Force	N (Newton)	lb (pound)
Charge	C (Coulomb)	
Energy J (Joule)	J (Joule)	BTU (British Thermal Unit)
Power	W (watt)	BTU/s

Conversion
1 m = 3.28 ft,
1 mi = 1.61 km, 1 ft = .305 m
1 year = 3.16×10^7 s
1 kg = 0.0685 slug, 1 slug = 14.6 kg
1 liter = 1.0×10^{-3} m ³ = 1.06 U.S. quarts
1 m/sec = 3.28 ft/s = 2.24 mi/hr,
1 mi/hr = 1.47 ft/s = .447 m/s
1 N = .225 lb, 1 lb = 4.44 N
$ e = 1.6 \times 10^{-19}$ C electron charge
1 electron-volt = 1.6×10^{-19} J, 1 calorie = 4.186 J,
1 erg = 10^{-7} J, 1 BTU = 1055 J
1 W = 1 J/s
1 horsepower = 746 W, 1 kW = 1000 W
1 N = 1 kg·m/s ²
1 J = 1 kg·m ² /s ²

Note: G in $F = Gm_1m_2/r^2$ is $G = \left\{ \begin{array}{l} 6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2 \\ 3.44 \times 10^{-8} \text{ lb}\cdot\text{ft}^2/\text{slug}^2 \end{array} \right\}$

k in $F = kq_1q_2/r^2$ is $k = 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2$