Welcome to 8.033!

Relation to other courses

8.20 covers 60% of material - either stay in 8.033 and coast through initially or take 8.224 ("Exploring Black Holes"). Taking both 8.20 and 8.224 waives the 8.033 requirement.

Surgeon General’s Warning

- **False sense of security**: Many of you will may think you know it all from books, other courses, *etc.* Don’t get lulled into false sense of security!

- **Unusual style**: Not everything is proven from the beginning (cf. 8.01 & 8.02). For SR, we’ll derive everything from Einstein’s 2 postulates, but for cosmo and GR we jump right into the middle and work out cool consequences from equations you’ll need to take at faith

- **Non-intuitive**: This may be your first real departure from intuitive physics.

- **Collaboration**: OK to collaborate on problem sets, but you *must* hand in your own work. Copying ==> trouble.

- **Night owls**: Like to stay up all night? View Friday as part of the weekend? Consider grad school & postdoc! No credit for late problem sets. Attendance crucial: saves you time, and beyond books, there’ll be ~ 30% value-added that you’re responsible for on exams. If you miss a lecture, see friend or TA.

- **Unfamiliar math**: Calculus of variations

- **Lots of PowerPoint**: Keep me from going to fast and erasing too soon
How to do well in the course:

- Come to class
- Use study guide
- Do all psets
- Study with someone else
- Don’t waste time on pset all-nighters with no help

I’ve never failed a student who really tried hard.

YOUR GRADE:
20% weekly problem sets
20% Quiz 1 (1 hour)
20% Quiz 2 (1 hour)
40% Final exam (3 hours)


**Lecture plan:**
- L1-5: Background
- L6-13: Special relativistic kinematics
- L14-23: Special relativistic dynamics
- L24-25: Relativity of E&M
- L26-29: Cosmology
- L30-39: Curved spacetime & black holes

See the detailed syllabus for a lecture-by-lecture list of topics. The GR part will be limited; we'll mostly work out consequences of FRW and Schwarzschild metrics, and perhaps whet your appetite for a full GR course.

**Reading:**
1. We'll start with Resnick (the whole book). On the side, browse French and (highly recommended!) Einstein. N.B. BOOK LATE!
2. For dynamics and E&M, we do French (5-8).
3. For cosmology, there will be handouts.
4. For black holes, we'll do Taylor & Wheeler.

Consider printing the lecture notes beforehand and writing notes on the during class.
The History of Physics in 10 minutes

1. Ancient civilizations (what limited them?)
2. Newtonian Mechanics (1600’s) (8.01, 8.06)
3. Electromagnetism (1800-1875) (8.02, 8.03, 8.07)
4. Stat Mech & Thermo (1850-1900)
6. Quantum Mechanics (1900-1926)
7. 1900’s breakthroughs
8. What’s left for you to do?
Newtonian Mechanics (1600’s)

- Tycho Brahe 1546-1601 Danish
- Johannes Kepler 1571-1630 German
- Sir Isaac Newton 1642-1727 English

Principia published 1678

Era of gravitational astronomy (1700’s)

- Leonhard Euler 1707-1783 Swiss
- Alexis Clairaut 1713-1765 French
- J. D’Alembert 1717-1783 French
- Joseph Lagrange 1736-1813 French
- Pierre Laplace 1749-1827 French

Era of electricity & magnetism (1800-1875)

- Carl F. Gauss 1777-1855 German
- André Ampere 1775-1836 French
- Michael Faraday 1791-1867 English
- Georg Ohm 1787-1854 German
- James C. Maxwell 1831-1879 Scottish

Statistical Mechanics & Thermodynamics (1850-1900)

- Clausius 1822-1888
- Joule 1818-1889
- Kelvin 1824-1907
- Helmholtz 1821-1871
- Maxwell 1831-1879
- Boltzmann 1844-1906
- Planck 1858-1947
Relativity

Albert Einstein  1899-1955
(Lorentz, Riemann, Schwarzschild, Kerr, FRWL, Wheeler, Kruskal, Hawking, ...)

Quantum Mechanics

Max Planck  1858-1947
Niels Bohr  1885-1962
Louie de Broglie Max Born  1882-1970
Werner Heisenberg  1901-1976
Erwin Schrödinger  1887-1961
Wolfgang Pauli  1900-1958
John von Neumann
Paul Dirac
Hugh Everett, III  1930-1982
Hans-Dieter Zeh
Einstein

In 1905, at age 26, while working in a patent office with almost no contact to academia, he wrote three monumental papers:

- Photoelectric effect
- Brownian Motion
- Special theory of relativity

Completed general relativity in 1916. Learn from his approach!
Hints of relativity in the physics you already know

Special relativity

Maxwell’s equations in vacuum imply

\[ \nabla^2 E - \frac{1}{c^2} \ddot{E} = 0. \]

- This implies (as you learned in 8.02) waves traveling at speed \( c \) at any frequency (big shock then — now observed over range \( 10^3 - 10^{27} \) Hz).

- But speed \( c \) relative to what? No reference to any particular frame.

- Consider flashlight on train. Either the equation is lacking something or something else is wrong. We’ll explore what the big deal is.
**General relativity**

Combining

\[ F = ma \]

with

\[ F = \frac{GmM}{r^2} \]

shows that the gravitational acceleration

\[ a = \frac{GM}{r^2} \]

is mass-independent as long as

“inertial mass” = “gravitational mass”.

Is it?

- Galileo’s Pisa experiment showed it with low precision.
- Eötvös (1890) and later others showed with high precision that \( a \) independent of both mass and composition (density, atomic element, matter/antimatter, etc.). Coincidence?
- In GR, Einstein explained it as gravity being a purely geometric effect. Follows from his equivalence principle.
Key lessons of the course

Special relativity

- Space and time are inextricably merged as 4D spacetime.
- Fast moving clocks appear slower, shorter and heavier.
- $E = mc^2$

General relativity

- Spacetime is not static but dynamic, globally expanding and locally curving and contracting to form black holes etc.
- Matter curves spacetime
- Things moving straight through curved spacetime appear deflected (gravity)

_________________________ ← (your theory here)

- Think for yourself.
- Question authority.
- Don’t dismiss ideas just because they sound weird.
Expect physics to feel weird!

- Relativistic driving movie
- Black hole movie
Next time:
symmetry
in physics