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Syllabus

Intermediate Modern Physics

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Physics 3710: Intermediate Modern Physics

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Physics 3710: Intermediate Modern Physics
Spring 2018

Meeting Times: 9:30-10:20 MWF
Meeting room: ENGR 104
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Physics 3710 is about the principles and applications of special and general relativity and of the nuclear and sub-nuclear structures of matter. Though some of the topics of 3710 are more than 100 years old, others continue to rapidly evolve—and their interplay provides a fascinating, **living example of science at work**. Moreover, the course is predicated on, and aspires to convey, two thoroughly modern, coherent, and interconnected themes: (1) the largest (e.g., stars, galaxies, and galactic clusters) and smallest (e.g., quarks, leptons, and force-carrying bosons) observed forms of matter are intimately related to one another; and (2) dynamics, conservation laws, and symmetry are all essentially equivalent.

Student Outcomes of Physics 3710 Will Include

Be able to:

- state how special relativity represents an intellectual revolution that requires completely different ways of thinking from classical physics
- state the experimental basis of special relativity
- define an “observer”
- define and use the Lorentz transformations
- define “time dilation” and “length contraction”
- describe the “twin paradox” and how it is resolved using “proper time”
- define and use energy-momentum conservation in collisions and bound states
- explain how electric and magnetic fields transform between observers
- state some of the practical consequences of special relativity
- state the experimental basis of general relativity
- explain how gravity can be understood as geometry
- write out the Schwarzschild proper time
- state some of the practical consequences of general relativity
- describe consequences of the Schwarzschild geometry for motion of test masses and light
- cite experimental evidence for “gravitational lensing,” and “gravitational radiation”
- cite experimental evidence for “cosmological expansion”
- write out the FLWR proper time
- list the observations that support the FLWR cosmology
- describe how to evaluate the “age of the universe”
- describe the motivation for and predictions of the Dirac Equation
- interpret Feynman diagrams for QED
- enumerate all of the fundamental particles in the “standard model”
- describe “color charge”
- interpret Feynman diagrams for QCD
- explain the origin of the mass of nucleons, atoms, molecules
- describe “weak charge”
- interpret Feynman diagrams for QFD
- define and cite an example of “parity violation”
- describe the origin of “electroweak unification”
- list important questions still unanswered in the standard model

Course Structure

Preamble: I predict that you will find Physics 3710 to be the most interesting physics course that you will take as an undergraduate. That said, I have to provide a **warning to the user** of this course. Because the course-content of 3710 changes almost daily it will probably always be a work in progress.

Textbooks: There is no required textbook for this course. Extensive notes for the course material are available at http://www.physics.usu.edu/peak/phys_3710/index.htm. Other potentially useful textual resources include: *The New Physics: For the Twenty-First Century*, by Gordon Fraser (Ed.) (Cambridge, 2 ed., 2006)—a terrific collection of essays on cutting-edge stuff that you would be well served reading—even the material not included in 3710; Chapters 11-14, in *Modern Physics*, by John Morrison; Chapters 2, 11, and 12, in *Modern Physics*, by Randy Harris (Addison-Wesley, New York, 2008); and Chapters 1, 11-13 in *Concepts of Modern Physics,* by Arthur Beiser (McGraw-Hill, New York, 2003) (beware that the latter is dated and possibly wrong in places). I also recommend that you obtain from the library two Scientific American Special Editions: *The Once and Future Cosmos* and *The Frontiers of Physics*. They both have extremely interesting (often provocative) content, written by eminent, practicing scientists, and we will be discussing material from each.

Web information: Material relevant to the course will appear from time-to-time on the course web site. This will be accessible by clicking on http://www.physics.usu.edu/peak/phys_3710/index.htm. I will probably want to contact you occasionally by email. The subject of any such mailings will be "physics 3710." Please (a) read your email regularly and (b) don't filter out "physics 3710" as junk mail!

Grading: Total points = 1000: (a) Homework quizzes = 200 points; (b) Hourly exams = 2x200 = 400 points; (c) Final exam = 400 points. The following indicates the number of points required to attain each grade level:

A ≥ 925, A- ≥ 900, B+ ≥ 875, B ≥ 825, B- ≥ 800, C+ ≥ 775, C ≥ 725, C- ≥ 700, D+ ≥ 675, D ≥ 600.

Homework problems: On the dates indicated below, there will be a ten-minute quiz on one of the problems assigned for that date. Each quiz will be worth 25 points. I strongly encourage you to work on the problems in teams well before the quiz date so you can ask questions in class or by email. If you have no questions I will assume you are master of the material.

Examinations: Examinations will consist primarily of qualitative questions designed to allow you to demonstrate your mastery of the course concepts. The final exam will be cumulative. A missed exam may be made up only if you have a written medical or similar excuse.

Attendance: Attendance is required. Any material presented in lecture may appear on examinations. Absent yourself from lecture at your own risk!!!!

Office hours (SER240): My formal office hours are MWF 10:30-11:30 AM. I'm around a lot of hours every day, so feel free to come see me at any time. If it is at all possible I'll be glad to make time to talk with you. Please call me—or better, send me an email to make sure that I'll be here when you come by.

Students with ADA-documented physical, sensory, emotional or medical impairments may be eligible for reasonable accommodations. Veterans may also be eligible for services. All accommodations are coordinated through the Disability Resource Center (DRC) in Room 101 of the University Inn, (435)797-2444 voice, (435)797-0740 TTY, (435)797-2444 VP, or toll free at 1-800-259-2966. Please contact the DRC as early in the semester as possible.

The last day to add this class is January 29. The last day to withdraw is March 22.

Physics 3710 – Calendar of Events – Spring 2018

Day	Date	Topic	Day	Date	Topic
M	1/08	BK: the big and the small	M	3/12	GR: inflation, COBE, WMAP
W	1/10	BK: Newtonian relativity	W	3/14	GR: dark energy, cosmo cons
F	1/12	SR: c is c; how?	F	3/16	GR: primordial nucleosynthesis
M	***1/15***	***Martin Luther King Day***	M	3/19	review
W	1/17	SR: s-t diagrams, Lorentz trans	**W**	**3/21**	**Exam II**
F	1/19	SR: relativistic kinematics	F	3/23	SM: periodic table, Schrodinger
M	1/22	SR: relativistic kinematics	M	3/26	SM: Dirac, antimatter, spin
W	1/24	SR: the problem with momentum	W	3/28	SM: QED, Feynman diag
F	1/26	SR: energy-momentum	F	3/30	SM: QED, renormalization
M	1/29	SR: collisions	M	4/02	SM: particle zoo, color,
W	1/31	SR: nuclei, fission, fusion	W	4/04	SM: LGT & QCD
F	2/02	SR: relativistic EM	F	4/06	SM: lattice QCD
M	2/05	review	M	4/09	SM: weak interaction phenomena
W	**2/07**	**Exam I**	W	4/11	SM: QFD, parity
F	2/09	GR: Newtonian gravity	F	4/13	SM: QFD, Higgs
M	2/12	GR: gravity as geometry I	M	4/16	SM: electroweak unification
W	2/14	GR: gravity as geometry II	W	4/18	SM: neutrinos, family mixing
F	2/16	GR: perihelion & light	F	4/20	SM: CP violation, mat/antimat
T*	2/20	GR: perihelion & light	M	4/23	SM: summary & open Qs
W	2/21	GR: black holes	W	4/25	SM: beyond the SM
F	2/23	GR: star collapse, grav radiation	F	4/27	review
M	2/26	GR: Gals, dark matt, red shifts	**M**	**4/30**	**Exam III 9:30-11:20**
W	2/28	GR: rel cosmology, expansion			
F	3/02	GR: CMB			
M	*3/05*	*Spring Break*			
W	*3/07*	*Spring Break*			
F	*3/09*	*Spring Break*			

BK = background,**SR** = special relativity
GR = general relativity,**SM** = structure of matter
[shaded box] = homework quiz date

Homework quiz dates (shaded): F 1/19, F 1/26, F 2/02, F 3/02, F 3/16, F 4/06, F 4/13, F 4/20.

*** M 2/19 classes held on T 2/20.**

The new periodic table

Fermions (spin = 1/2)

First generation	Second generation	Third generation	Electric charge
	Leptons		
Electron neutrino, ν_e	Mu neutrino, ν_μ	Tau neutrino, ν_τ	0
Electron, e	Muon, μ	Tau lepton, τ	–e
	Quarks		
Up quark, u	Charm quark, c	Top quark, t	+2e/3
Down quark, d	Strange quark, s	Bottom quark, b	–e/3

Gauge bosons (spin = integer)

Name	Interaction	Electric charge	Spin
Graviton*	Gravity	0	2
W^+, W , Z^0, photon	Electroweak	+e, –e, 0, 0	1
Gluon	Color (strong)	0	1

* Not yet observed

Higgs boson

In the standard model of particle physics, massive particles “acquire” their masses via interactions with the “Higgs field.” The Higgs boson (Leon Lederman’s much publicized “god particle”) is an excitation of this field and, in its simplest version, is predicted to have zero spin, zero color charge, but nonzero weak charge. The masses of particles carrying weak charge, including the Higgs boson itself, result from their “plowing through” the Higgs field. Experiments at the Large Hadron Collider (LHC) show clear evidence of a previously unknown, electrically neutral particle, with spin equal zero, and mass of about 125 GeV/c^2. It is (almost) universally regarded as the long sought after Higgs boson.

A few of the heroes of this course

James Clerk Maxwell (1831-1879)
Albert Einstein (1879-1955)
Emmy Noether (1882-1935)
P.A.M. Dirac (1902-1984)
Henrietta Leavitt (1868-1921)
Edwin Hubble (1889-1953)
Lise Meitner (1878-1968)

Richard Feynman (1918-1988)
Ralph Alpher (1921-2007)
Chien-Shiung (Madame) Wu (1912-1997)
Chen-Ning Yang (1922-)
Steven Weinberg (1933-)
Vera Rubin (1928-2016)
Frank Wilczek (1951-)

How many of these names do you recognize? Do you know what they did that was so important? We’ll be talking about all of them and their contributions.