Physics 611: Quantum Field Theory II

Winter-Spring 2014

TuTh 11:30-12:50   P128

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Summary Course Description

In the first semester, Phy. 610, we developed the basic methods of quantum field theory, including spacetime and internal symmetries, canonical quantization, the interaction picture for Green functions, perturbation theory, the relativistic S-matrix, cross sections, and wound up with an introduction to the quantization of fields with spin. In this semester, we will introduce renormalization and the renormalization group, and the further development of relativistic quantum fields in the Standard Model. We will also discuss the path integral formulation for quantum fields, and the ideas of effective field theory. The material in the course will follow the categories listed below.

Outine

1. **Loops and Renormalization for Scalar Fields**
   - loop integrals
   - dimensional regularization
   - counterterms and renormalization theorems
   - the renormalization group for ϕ_4^4 and ϕ_6^3
2. **Introduction to Path Integrals**
   - path integrals for quantum mechanics
   - path integrals for scalar fields

3. **Fields with Spin**
   - classical spinor fields, the Dirac equation and algebra
   - classical vector fields and the Proca Lagrangian
   - classical abelian and nonabelian gauge theories; the Yang-Mills Lagrangian
   - quantization: anticommutation relations for spinors
   - fermionic path integrals
   - gauge fixing for vectors and ghost fields
   - supersymmetry algebra
4. **Symmetry Breaking and the Standard Model**
   - the Higgs mechanism
   - the electroweak sector
   - quantum chromodynamics
   - discrete symmetries
5. **The Standard Model at Tree Level**
   - perturbation theory rules
   - dimensional regularization for gauge theories
   - μ decay
   - quark pair production
6. **Loops and Unitarity.**
   - Ward identities
   - role of ghost fields
   - cut diagrams
   - infrared safety
7. **Renormalized Gauge Theories**
   - loop corrections for quantum electrodynamics (QED) and then quantum chromodynamics (QCD).
   - electron anomalous magnetic moment
   - the QED running coupling and the 'Landau pole'
   - asymptotic freedom in QCD
   - infrared finiteness in QED, infrared safety for QCD
8. **Introduction to effective field theory**

Outcomes

Physics 611is intended to provide the student with an understanding of theoretical developments that led to and underly the contemporary Standard Model of fundamental particles and forces. It should provide the student to the threshold of advanced study and research in areas that use quantum field theory, including particle physics, condensed matter physics and string theory

Grades

A grade for this course will reflect the results of:

1. Homework. Homework will be assigned each week, and will be due at the lecture one week later, except when otherwise arranged. Homework assignments and solutions will be available at the same web page as for Physics 610 last semester,

   http://insti.physics.sunysb.edu/~sterman/P610/index.html

2. (Possible) midterm and (definite) final examination. If held, the midterm will be relatively late in the semester. The final exam is scheduled for 5:30 – 8:00 PM, May. 14, 2014.

3. Short ($\leq$ 5 pages) paper, discussing one or more applications of the course material in the recent literature.

Office Hours

I should be available for discussion after class, and in my office 2 - 4 Tuesdays. I'm there most of the time anyway, so you might drop by, but I may not be available at all other times.

For Your Consideration

University policy prescribes that the following information be included in all course syllabi.

Americans with Disabilities Act: If you have a physical, psychological, medical or learning disability that may impact your course work, please contact Disability Support Services, ECC(Educational Communications Center) Building, Room 128, (631)632-6748. They will determine with you what accommodations, if any, are necessary and appropriate. All information and documentation is confidential.

Academic Integrity: Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty, please refer to the academic judiciary website at http://www.stonybrook.edu/uaa/academicjudiciary/

Critical Incident Management: Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of University Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.

Recommended Books now on Reserve in Math-Physics Library

Others may be put on reserve as appropriate.

- J.D. Bjorken and S.D. Drell, *Relativisitic Quantum Mechanics* and *Relativistic Quantum Fields*, 1966. A classic; follows a very different route than ours.

- C. Itzykson and J.B. Zuber, *Quantum Field Theory*, 1980. A lot of material, a lot of pages: small print, and smaller print. Has a treatment of renormalization of gauge fields based on generating functional formalism.

- M.E. Peskin and D.V. Schroder, 1995, *Introduction to Quantum Field Theory*.

- P. Ramond, *Quantum Field Theory, a Modern Primer*, 1981. Not so modern any more, but succinct and to the point. Good, streamlined treatment of ϕ^4 renormalization. One of the few texts to have an introduction to the Poincaré group.

- G. Sterman, *An Introduction to Quantum Field Theory*, 1993. My book; the one we will mainly follow.

- M. Srednicki, *Quantum Field Theory*, 2007.

- S. Weinberg, *Quantum Theory of Fields*, 1995. Vols. 1, 2. Emphasizes some of the same issues as in our course, but at a mathematically more rigorous level. What Weinberg has to say is always worth reading.