PHYSICS 714
ADVANCED QUANTUM THEORY II
SPRING 2012

Meeting time: Tuesday and Thursday 11:00 am - 12:15 pm

Place: PSC 602

Office hours: Monday 1:30 - 3:30 pm

Instructor: Professor Pawel O. Mazur

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The purpose of the course is to introduce to graduate students of physics the more advanced concepts of Quantum Field Theory (QFT) and to teach them the modern methods of computations in QFT on examples ranging from Quantum Electrodynamics (QED) to non-Abelian Gauge Theories (NAGT) which are the basis of the Standard Model of elementary particle theory. In this course the Feynman diagram techniques and the methods of regularization of divergent loop integrals will be developed for specific QFTs such as QED and the interacting scalar Φ^3 theory. The method of functional integrals in QFT and the Pauli-Villars and dimensional regularization schemes will be introduced. The renormalization of perturbative QED at the one-loop level will be developed. This includes the charge or coupling constant renormalization, the fermion mass renormalization, and the wave function renormalization. The method of counterterms will be introduced. Several examples of radiative corrections in QED will be computed. A short introduction to non-Abelian gauge theories and the Brout-Englert-Higgs mechanism of spontaneous symmetry breaking will be given. By the end of this course the student will be able to compute Feynman diagrams in QFTs such as QED and the interacting scalar Φ^3 theory. The student will also be able to compute scattering cross-sections for simple scattering processes in QFTs.

The prerequisites to this course are PHYS 701, 703, 704, 711, 712 and 713

Texts:

Quantum Field Theory, by C. Itzykson and J.-B. Zuber

Dover Publications, 2005, ISBN - 13: 978-0-486-44568-7; ISBN - 10: 0-486-44568-2

Quantum Field Theory, by Mark Srednicki

Cambridge University Press, 2009, ISBN 978-0-521-86449-7

The prepublication draft of this book is available on Professor Srednicki's website

http://web.physics.ucsb.edu/ mark/qft.html

Instructional delivery strategy: In this course I will lecture on the material which can be found in the selected chapters of two books which are listed above. I did all the necessary derivations of formulae and computations and I have included them in my lecture notes. The material which is covered in my lectures is not so easy therefore I will be performing all the necessary computations on a blackboard, showing you at the same time how to do the computations in QFT. Some parts of these computations will be left for you to complete as a homework assignment. 80 percent of the material covered in this course will be in the form of lectures and 20 percent in the reading assignments.

Reading assignments: The relevant chapters (sections) of the books listed above should be read prior to and after the class. The reading assignments for the next class will be given at the end of the earlier class.

Homeworks: There will be no tests given during the class. 8 homeworks will be assigned during the course. This amounts to an approximately one homework per two weeks. Solving homework problems will involve sometimes lengthy computations and this is why you will have two weeks to complete those computations. You are welcome to visit my office, preferably during my office hours, if you will need help with the course material and with your homeworks. Your homework grade will count toward 80 percent of your course score.

Final exam: The final exam is comprehensive and will cover all material covered in class. The final exam counts toward 20 percent of your course score. All students must take the final exam.

Grading: Each homework carries a weight of 20 points. The final exam counts for 40 points. The maximal number of points is therefore 200. The translation of the course score to letter grade will occur only when the complete scores have been calculated after the final exam. The ranges of grade of A, B, C, D, and F are traditional for this course. A (score $\geq$ 170), B (score $\geq$ 150), C (score $\geq$ 130), D (score $\geq$ 110), F (score $\leq$ 100).

PHYS 714 TIME TABLE

Week 1. Interaction picture and the invariant perturbation theory in QFT.
The chronological product and the Schwinger-Dyson series.

Week 2. S-matrix. Scattering cross-sections.

Week 3. Quantum Electrodynamics (QED). The free particle Feynman propagators.
Introducing Feynman diagrams.

Week 4. The second order processes in QED 1. Vacuum polarization.
Photon propagator and charge renormalization.

Week 5. The second order processes in QED 2. Electron self-energy.
Fermion propagator and mass renormalization.

Week 6. The second order processes in QED 3. Vertex function.
Anomalous magnetic moment for an electron at one-loop.

Week 7. Renormalization of perturbation theory in QED. Ward identities and gauge invariance.

Week 8. Green functions and the S-matrix. Lehmann-Symanzik-Zimmermann reduction formula.

Week 9. Spring break.

Week 10. Functional integral methods in QFT. Deriving Feynman rules using the functional integral.
Φ^3 QFT as an example.

Week 11. Symmetries and spontaneous symmetry breaking. Lie groups and Lie algebras.

Week 12. Introduction to non-Abelian gauge theories.

Week 13. Glashow-Weinberg-Salam model of electro-weak interactions.
The Brout-Englert-Higgs mechanism and masses of W and Z bosons.

Week 14. Non-Abelian gauge theories I. Quantization.

Week 15. Non-Abelian gauge theories II. Asymptotic freedom.

The final exam will take place on **Saturday, April 28, 2012, 2:00-5:00 pm.**

Attendance policy: Attendance highly suggested. No more than three classes may be missed. The material covered during the classes which were missed must be mastered by a student.

Office of Student Disability Services policy statement: Any student with a documented disability should contact the Office of Student Disability Services at 803-777-6142 to make arrangements for appropriate accommodations.