Quantum Field Theory – Course Summary

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Syllabus

- Reminder of Lagrangian and Hamiltonian mechanics. Introduction of Lagrangian and Hamiltonian field theory. Importance of Poisson brackets. (3hours)
- Quantization of a free scalar field theory. Introduction of creation and annihilation operators and canonical quantization. (3 hours)
- Introduction of point interactions. Calculation of scattering matrix elements and LSZ reduction formula. Wicks theorem and normal ordering. Generating functionals and origin of Feynman diagrams. (4 hours)
- Quantization for fermionic fields. Recap of relativistic quantum mechanics and symmetries in fermionic systems. (2 hours)
- Creation and annihilation operators for fermions and anticommutation relations. (3 hours)
- Quantization of photon field and necessity for gauge fixing. (2 hours)
- Origin of Feynman rules in QED. Simple examples. (3 hours)
- Introduction to renormalization. Ultraviolet divergences and their regularization. Counterterms and origin of running masses and couplings. Implications for physics. (5 hours)
- Introduction to path integral techniques. Quantization of nonabelian gauge theories. (5 hours)

Objectives

- For a particular particle content, to be able to identify the form of the Lagrangian for the corresponding Quantum Field Theory.
- To obtain, with justification, the Feynman rules for the Theory.

- To be able to construct operators for basic physical quantities for simple Field Theories, and obtain and interpret expectation values.
- To be able to calculate matrix elements and cross-sections at tree level, and in the most basic cases at one loop.
- To be able to isolate ultraviolet divergences, and explain the relevance of these in terms of running masses, couplings, *etc.*.

Prerequisites
A knowledge of most, if not all, of the below topics will be useful.

- Basic complex analysis.
- Formulation of quantum mechanics in both Schrodinger and Heisenberg pictures, and use of Dirac notation.
- Raising and lowering operator techniques in quantum mechanics.
- Perturbation theory in quantum mechanics.
- Basic classical field theory.
- Relationships between symmetries and conservation laws in both quantum mechanics and classical mechanics/field theory.
- Relativistic electromagnetic theory, i.e. use of scalar and vector potentials and relationship to electromagnetic fields in four-vector notation.
- Quantum mechanics of particles in an electromagnetic field.
- Introduction to relativistic quantum mechanics.

Books
Some suggested books for the course are:

- An Introduction to Quantum Field Theory (Frontiers in Physics), Peskin and Schroeder.
- Quantum Field Theory, Mandl and Shaw.
- Gauge Theories in Particle Physics, Aitchison and Hey.
- Quantum Field Theory, Shrednicki.
- The Quantum Theory of Fields, Weinberg.