Relativistic Quantum Mechanics
Outline syllabus Autumn 2010

The course comprises 10 one hour lectures (two per week).

Special Relativity:

Revision of Lorentz Invariance – Lorentz Transforms and Form Invariance of Equations.
Revision of 4-vectors and operators.

Maxwell's Equations:

Conversion to Lorentz Invariant form.
Use of Lorenz Condition to derive field-current equation.

Quantum Mechanics:

Revision of postulates, especially operators, and the Schroedinger Equation.
Lorentz Variance of the Schroedinger Equation.

The Klein-Gordon Equation:

Derivation by quantizing $E^2=\mathbf{p}^2+m^2$.
Derivation of the 4-current.
Energy eigenvalues – discussion of negative energies and currents.
Pauli-Weisskopf and Feynman-Stueckelberg interpretations of negative currents.

Particle Scattering:

Modelling of scattering as a transition rate caused by a perturbing potential.
Time-dependent Perturbation Theory – emphasizing expansion as a power series.
Derivation of Transition Amplitude and Fermi's Golden Rule.
Graphical representation of zero to second order terms in the Transition Amplitude.

Scattering of Charged Spin-0 Particles:

Derivation of the interaction potential via coupling Klein-Gordon to Electromagnetic Field.
Derivation of the Transition Amplitude for a single particle coupled to a field.
Modelling of scattering as a second particle acting as a source for the external field.
Derivation of the Transition Amplitude for two particle scattering.

Feynman Rules to Cross-Sections:

Graphical representation of the terms in the Transition Amplitude.
Graphical calculation of Transition Amplitudes.
How measurable quantities are obtained from a Transition Amplitude.
Mandelstam Variables and Crossing Symmetry.
Examples: Cross-Sections for spinless electron-muon and electron-electron scattering.

The Dirac Equation:

Dirac's derivation from a linear Hamiltonian – properties and solutions as spinors.
Derivation of the 4-current and comparison with the Klein-Gordon Equation.
Eigenvalues of free particles - existence of spin and helicity as new quantum numbers.
Negative energy solutions - Antiparticles.

Scattering of Charged Spin-1/2 Particles:

Derivation of the interaction potential via coupling Dirac to Electromagetic Field.
Derivation of the Transition Amplitude for spin-1/2 scattering and resultant Feynman Rules.
Example: Transition Amplitude for spin-1/2 electron-muon scattering.
Problem of spin – Reduction of amplitude to product of Traces, and Trace Theorems.
Crossing Symmetry to quickly obtain electron-position annihilation to muon-antimuon.
Comparison with experiment.