Relativistic Quantum Mechanics - Video course

COURSE OUTLINE

Dirac and Klein-Gordon equations, Lorentz and Poincare groups, Fundamental processes of Quantum Electrodynamics.

COURSE DETAIL

MODULE 1 KLEIN-GORDON AND DIRAC EQUATIONS

Lecture 1 - Introduction, The Klein-Gordon equation
Lecture 2 - Particles and antiparticles, Two component framework
Lecture 3 - Coupling to electromagnetism, Solution of the Coulomb problem
Lecture 4 - Bohr-Sommerfeld semiclassical solution of the Coulomb problem, The Dirac equation and the Clifford algebra
Lecture 5 - Dirac matrices, Covariant form of the Dirac equation, Equations of motion, Spin, Free particle solutions
Lecture 6 - Electromagnetic interactions, Gyromagnetic ratio
Lecture 7 - The Hydrogen atom problem, Symmetries, Parity, Separation of variables
Lecture 8 - The Frobenius method solution, Energy levels and wavefunctions
Lecture 9 - Non-relativistic reduction, The Foldy-Wouthuysen transformation
Lecture 10 - Interpretation of relativistic corrections, Reflection from a potential barrier
Lecture 11 - The Klein paradox, Pair creation process and examples
Lecture 12 - Zitterbewegung, Hole theory and antiparticles
Lecture 13 - Charge conjugation symmetry, Chirality, Projection operators, The Weyl equation
Lecture 14 - Weyl and Majorana representations of the Dirac equation, Unitary and antiunitary symmetries
Lecture 15 - Time reversal symmetry, The PCT invariance
Lecture 16 - Arrow of time and particle-antiparticle asymmetry, Band theory for graphene
Lecture 17 - Dirac equation structure of low energy graphene states, Relativistic signatures in graphene properties

MODULE 2: LORENTZ AND POINCARE GROUPS

Lecture 18 - Groups and symmetries, The Lorentz and Poincare groups

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Physics

Pre-requisites:

1. Non-relativistic quantum mechanics, Special relativity

Coordinators:

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Lecture 19 - Group representations, generators and algebra, Translations, rotations and boosts
Lecture 20 - The spinor representation of SL(2,C), The spin-statistics theorem
Lecture 21 - Finite dimensional representations of the Lorentz group, Euclidean and Galilean groups
Lecture 22 - Classification of one particle states, The little group, Mass, spin and helicity
Lecture 23 - Massive and massless one particle states
Lecture 24 - P and T transformations, Lorentz covariance of spinors
Lecture 25 - Lorentz group classification of Dirac operators, Orthogonality and completeness of Dirac spinors, Projection operators

MODULE 3: QUANTUM ELECTRODYNAMICS
Lecture 26 - Propagator theory, Non-relativistic case and causality
Lecture 27 - Relativistic case, Particle and antiparticle contributions, Feynman prescription and the propagator
Lecture 28 - Interactions and formal perturbative theory, The S-matrix and Feynman diagrams
Lecture 29 - Trace theorems for products of Dirac matrices
Lecture 30 - Photons and the gauge symmetry
Lecture 31 - Abelian local gauge symmetry, The covariant derivative and invariants
Lecture 32 - Charge quantisation, Photon propagator, Current conservation and polarisations
Lecture 33 - Feynman rules for Quantum Electrodynamics, Nature of perturbative expansion
Lecture 34 - Dyson's analysis of the perturbation series, Singularities of the S-matrix, Elementary QED processes
Lecture 35 - The T-matrix, Coulomb scattering
Lecture 36 - Mott cross-section, Compton scattering
Lecture 37 - Klein-Nishina result for cross-section
Lecture 38 - Photon polarisation sums, Pair production through annihilation
Lecture 39 - Unpolarised and polarised cross-sections
Lecture 40 - Helicity properties, Bound state formation
Lecture 41 - Bound state decay, Non-relativistic potentials
Lecture 42 - Lagrangian formulation of QED, Divergences in Green's functions, Superficially divergent 1-loop diagrams and regularisation
Lecture 43 - Infrared divergences due to massless particles, Renormalisation and finite physical results
Lecture 44 - Symmetry constraints on Green's functions, Furry's theorem, Ward-Takahashi identity, Spontaneous breaking of gauge symmetry and superconductivity
Lecture 45 - Status of QED, Organisation of perturbative expansion, Precision tests

References:

1. J.D. Bjorken and S.D. Drell, Relativistic Quantum Mechanics, McGraw-Hill (1964).
2. S. Gasiorowicz, Elementary Particle Physics, John Wiley

& Sons (1966).
3. J.J. Sakurai, Advanced Quantum Mechanics, Benjamin/Cummings (1967).
4. M.E. Peskin and D.V. Schroeder, An Introduction to Quantum Field Theory, Addison-Wesley (1995).
5. S. Weinberg, The Quantum Theory of Fields, Volume 1: Foundations, Cambridge University Press (1995).