Physics 622, Introduction to Elementary Particle Physics, will be offered in Fall 2002. This course is recommended for both theory and experimental students in particle physics. The course will involve a thorough exploration of the structure of the standard model, the associated phenomenology, the field-theoretic calculational techniques, and some discussion of beyond the standard model possibilities.

Classes will be held on Mondays and Fridays from 11:00-12:30, starting Friday Sept. 6 through Monday, Dec. 9. They will be held in Towne 319, which is a specialized classroom with video-conferencing facilities. Students at Fermilab will be able to participate remotely from the CDF video-conferencing facility, reserved MF from 10:00-11:30. There may also be a Princeton link. Walt Kononenko (215-898-7572, wk@upenn5.hep.upenn.edu) will coordinate the videoconferencing.

The major topics will be

- Review of perturbative field theory
- Lie groups and algebras
- Nonabelian gauge theories
- Quantum Chromodynamics
- The standard electroweak theory
- Beyond the standard model (e.g. supersymmetry, grand unification)

Each section will include relevant formalism, phenomenology, and experimental results. A more detailed syllabus is given below.

The course will loosely follow chapters 5-10 of the book *Electroweak Interactions* by Peter Renton.

There are no formal prerequisites. However, a working knowledge of Feynman diagrams for fermions, photons, and scalars will be assumed, equivalent to chapters 3 and 4 of Renton. Elementary background in particle physics and other topics equivalent to chapter 1 and the first four sections of chapter 2 will also be assumed.
Syllabus

The tentative syllabus is given. It may be necessary to eliminate some topics.

• Review of perturbative field theory
  - Lagrangians, propagators, and Feynman rules for real and complex scalars, fermions, and massless and massive vector fields
  - Cross section and decay width formulae
  - Tree level examples from $\phi^3$, $\phi^4$, $\pi N$ (without isospin), scalar and fermion electrodynamics, $eP$ with form factors, hyperon decays, weak $\nu e$ processes
  - Loop effects
  - QED overview

• Lie groups and algebras
  - Basic concepts
  - $SU(2)$ and $SU(3)$
  - Global symmetries in field theory
  - Explicit and spontaneous breaking; the Goldstone theorem

• Nonabelian gauge theories
  - Abelian gauge symmetries
  - Structure of non-abelian gauge symmetries
  - Feynman rules without spontaneous breaking

• Quantum Chromodynamics
  - Lagrangian and rules
  - Asymptotic freedom and infrared slavery
  - Short distance physics
    * $e^+e^- \rightarrow$ hadrons
    * Deep inelastic scattering
    * High $p_T$ hadron scattering
  - Long distance physics
    * Confinement
    * The flavor symmetries $SU(2)$, $SU(3)$
    * Chiral symmetry
• The standard electroweak theory
  - The Fermi and IVB theories
  - Weak processes: $\mu$ decay, $\beta$ decay, $\pi_{l2,3}$ decays, strangeness, Cabibbo theory
  - Discrete symmetries $P, C, CP, T$
  - The $SU(2) \times U(1)$ model
    * Basic structure
    * The Higgs mechanism
    * The Lagrangian after SSB
  - Consequences and tests
    * Gauge interactions of fermions, weak neutral current
    * Gauge bosons and their self-interactions
    * The Higgs sector
    * The CKM matrix
    * $K$ and $B$ physics, penguins, heavy quark expansion, $CP$ violation
  - Neutrino mass and implications
    * Neutrino mass mechanisms
    * Neutrino oscillations
    * Neutrinoless double beta decay
    * The neutrino spectrum

• Beyond the standard model
  - Motivations
  - Unification or compositeness
  - Extended gauge groups and exotics
  - Grand Unification
  - Supersymmetry (qualitative)
  - Strings (qualitative)
Bibliography


- Supplementary materials on web

- Recommended books (on reserve)

- Other recommended books