Physics G8069
homework #3
due Mon. Oct. 2

1. **Quark spin**

   Two-jet production in e^+e^- collisions can be understood as a tree-level QED-like process $e^+e^- \to \gamma \to q\bar{q}$ followed by hadronization of the quark and antiquark. Assuming the quark and antiquark don't interact significantly, each jet carries the full momentum of its parent quark or antiquark. The distribution of jets with respect to the scattering angle θ carries information about the spin of a quark. References: there's some discussion in Cheng & Li p. 215-216, and for a nice picture see p. 9 in Quigg.

   (i) Suppose the quark is a spin-1/2 Dirac fermion with charge Q and mass M. What is the center of mass differential cross section for the process $e^+e^- \to q\bar{q}$? You should average over initial spins and sum over final spins, also you should keep track of the dependence on both the electron and quark masses.

   (ii) Now suppose the quark is a spinless particle that can be modeled as a complex scalar field with charge Q and mass M. Re-evaluate the center of mass differential cross-section for $e^+e^- \to q\bar{q}$. You should average over the initial e^+e^- spins. The Feynman rules can be found in appendix B.5 of Quigg, or in problem 9.1 in Peskin & Schroeder.

   (iii) In the high-energy limit the electron and quark masses are negligible and the angular distribution simplifies. For spin-1/2 quarks there's a nice explanation for the angular distribution at high energies: we talked about it in class, or see Peskin & Schroeder sect. 5.2 or Halzen & Martin sect. 6.6. What's the analogous explanation for the high energy angular distribution of spinless quarks?