## PHY611; Adv. QM + Intro. QFT. Problem Set 6

Due Wed. 26 Oct 2005 at the beginning of class.
n.b. Use natural units $\hbar = c = 1$ in all problems.

## 1. Potential scattering of Dirac fermions II

Our result for the Mott cross section was derived assuming that the potential transforms as the time component of a vector potential, hence has a vertex $-ie\gamma^0$. If instead the photon was a Lorentz scalar particle the corresponding vertex would be $-ie$, so the polarized Rutherford differential cross section

$$\frac{d\sigma}{d\Omega} = \frac{4m^2\alpha^2}{\vec{q}^4} \left|\bar{u}_{p's'}\gamma^0 u_{ps}\right|^2 \tag{1}$$

would become instead

$$\frac{d\sigma}{d\Omega} = \frac{4m^2\alpha^2}{\vec{q}^4} \left|\bar{u}_{p's'} u_{ps}\right|^2 \ . \tag{2}$$

(*10 pts*) Use trace techniques to derive the corresponding *unpolarized* "scalar Mott" differential cross section as a function of scattering angle $\theta$.

## 2. Some real numbers.

a) (*4 pts*) B factories are machines that produce B mesons from the decay of the 4S $\Upsilon$ $b\bar{b}$ resonance at an $e^+e^-$ collider. Given the PDG mass of the 4S $\Upsilon$ and an electron energy of 12 GeV, approximately what positron energy would required to operate this collider?

b) (*3 pts*) It has been suggested to use the new GSI antiproton facility being constructed in Darmstadt to study $J/\psi$ interactions with nucleons by making the $J/\psi$ from an antiproton beam on a nuclear target. Approximately what momentum in GeV (frequently written as GeV/c) must an antiproton beam incident on a rest nucleus have for this application? (The reaction is $p\bar{p} \to J/\psi$ followed by $J/\psi$-nucleon scattering. Neglect Fermi motion, so that initial $p$ is at rest.)

c) (*3 pts*) In part b), what is the single value of $\mathrm{E}_{cm}$ of the $J/\psi$-nucleon system that can be studied in this fashion?

## 3. Feynman diagrams and amplitudes for other QED processes.

Draw the Feynman diagrams and write the invariant amplitudes to $O(\alpha)$ for the processes

a) (*2.5 pts*) Compton scattering (elastic $\gamma e^-$ scattering);

b) (*2.5 pts*) Electron-electron scattering (elastic);

c) (*2.5 pts*) Bhabha scattering (elastic $e^+e^-$ scattering);

d) (*2.5 pts*) Two-photon pair production ($\gamma\gamma \to e^+e^-$).