Elementary Particle Physics: Assignment # 4

Due Monday Nov 6th 4:10 pm

1. Draw the tree level QED Feynman diagrams and use the Feynman rules to write the amplitude M of the following processes (For each particle (p_i, s_i) or (p_i, λ_i) labels its four-momentum and its helicity)
   - label the momenta and particles in the graphs according to the notation I give (in drawing the diagram assume that times runs form left to right as it is done in class).
   - Make sure that in each amplitude you specify the momentum in the propagator in terms of the momenta of the external legs
   - justify what you write. You can consult all books which have these processes or related ones, but write the result in the notation I give you and with the time arrow as I said.

   1.1 Moller Scattering of positrons: $e^+(p_1, s_1)\ e^+(p_2, s_2) \to e^+(p_3, s_3)\ e^+(p_4, s_4)$

   1.2 Compton Scattering on positrons: $e^+(p_1, s_1)\ \gamma(p_2, \lambda_2) \to e^+(p_3, s_3)\ \gamma(p_4, \lambda_4)$

   1.3 Pair annihilation: $e^-(p_1, s_1)\ e^+(p_2, s_2) \to \gamma(p_3, \lambda_3)\ \gamma(p_4, \lambda_4)$

2. Using the chiral representation of the 4-spinors given in homework 1, compute the square of the Feynman amplitude generated by QED process for the process $e^+e^- \to \mu^+\mu^-$ (for simplicity take the massless fermion limit) for the 16 spinor configurations . Compare with the corresponding results we discussed in class for the Yukawa interaction. Reason the answer.

3. The lagrangian for electromagnetic interactions of an electron ψ (charge -1 and mass m) and a scalar ϕ of charge e_i and mass m_s with an electric field (photon) A is

   $$\mathcal{L} = \bar{\psi}\,(i\partial_\mu\gamma^\mu - e\gamma^\mu A_\mu - m)\,\psi + [(\partial_\mu + iee_iA_\mu)\phi][(\partial^\mu + iee_iA^\mu)\phi]^\dagger - m_s^2|\phi|^2$$

   3.1 Draw the Feynman diagram for $e^-(k, r) + s(p) \to e^-(k', r') + s(p')$ and show that the Feynman amplitude for the scattering is

   $$M = \frac{e^2 e_i}{q^2}\bar{u}^{r'}(k')(\not{p}\ +\ \not{p}')u^r(k)$$

   3.2 Obtain the unpolarized squared amplitude and the corresponding differential cross section $\frac{d\sigma}{dE'd\Omega}$ in the LAB system (where $p = (m_s, 0)$). Neglect the electron mass. As usual E' and Ω are the corresponding energy and solid angle of the outgoing electron.

   3.3 With the results above obtain the differential cross section $\frac{d\sigma}{dE'd\Omega}$ for the DIS $e^-p \to e^-X$ in a parton model with partons being scalars.

   3.4 Predict the expected scaling and relations between the form factors F_1^{ep} and F_2^{ep} in this scalar-parton model