# Spring Quarter 2015
# UCSD Physics 214
# Final Exam

## All Questions, are due on Friday, June 12th, 2015, at 2pm.

*This is an open book exam in the sense that you are welcome to use any of the references listed or linked in on the course web site, including Halzen & Martin. You will need a computer to do some of the plots requested. You will need to look some things up in the particle data book, and may do so either online or on paper.*

*You are not allowed to use solution sets from previous year's class, as many of the problems are similar to problems from previous years.*

1. **26 Points:** As mentioned in class, the e+e- -> qqbar process receives contributions form intermediate virtual photon or Z. The latter is a weak process. You will see weak interactions in Physics 222. Nevertheless, given the Feynman rules for Z-exchange processes, you should already be able to calculate the full cross section.

   Consider the process e+e- -> bbbar . The first order weak matrix element for this process is given in Halzen & Martin eq. 13.57. (Actually you will have to adjust 13.57 from e+e- -> mu+mu- to bbbar in the final state!)

   a. Start from 13.57 and show how to get to 13.60. Make sure that you understand the definition of the angle theta. Is it the angle between e- and mu-, or e- and mu+ ?
   b. Modify equation 13.60 appropriately for the bbbar final state. Then plot the total cross section for e+e- to bbbar for center of mass energies from 20GeV to 150GeV. (Use a computer, use a log scale, and sensible units like nbarn or microbarn) On the same graph, also plot the purely QED cross section. (The vector and axialvector couplings, cv and cA of fermions are given in Table 13.2) Use $\sin^2\theta_W = 0.23$, and look up the mass and width of the Z in the particle data book.
   c. Calculate the forward-backward asymmetry $A_{fb}$ (see equation 13.65) as a function of the center of mass energy. Plot it in the interval 20-150GeV. The first measurement of this was made in 1984 (PL B146, 437, 1984), and showed that the b-quark is a down-type quark.

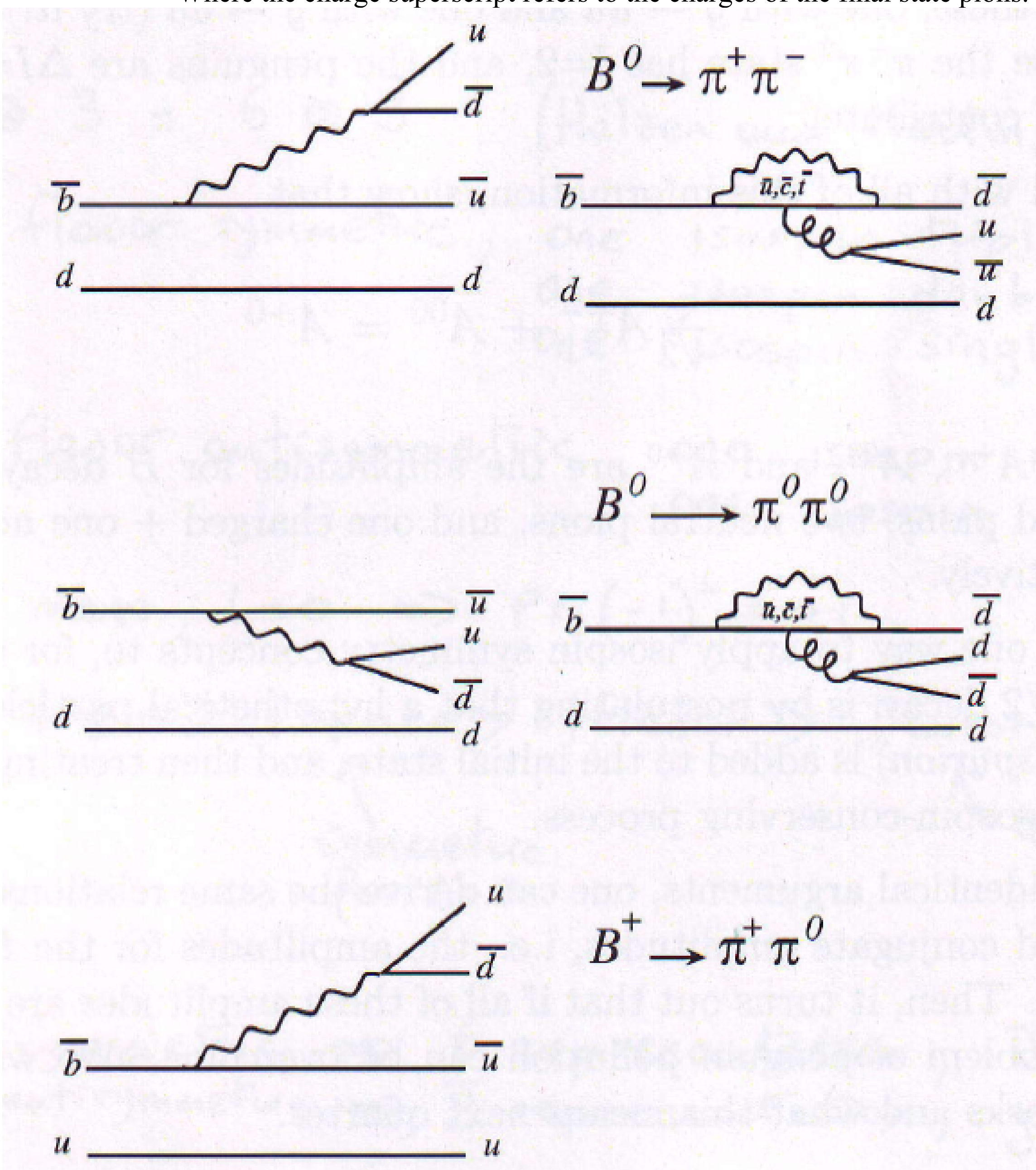
2. **10 points:** Consider $J^P$ = -1 mesons with zero strangeness that can be built from u,d, and s quarks and anti-quarks.
    a. What are the flavor wave functions of rho+-0, omega, and phi ?
    b. What is the color wave function ?
    c. What is the spin wave function for Jz=0 ?
3. **8 points:** Consider the process e+e- -> Upsilon(4S) -> B+B- .The Upsilon(4S) is a bbbar bound state with quantum numbers $J^{PC} = 1^{--}$ . What is the angular distribution of the B-mesons in the center of mass? Explain your reasoning.
4. **10 points:** Let A, B, C be pseudoscalar mesons. Let D be a vector meson (NOT an axial vector meson). Which of the following decays if any is allowed if parity is conserved? Explain your reasoning.
    a. A -> BC
    b. D -> BC
    c. D -> BC if B and C are identical particles.
5. **10 points:** Consider the $\text{Omega}^-$ (S=-3, I=0) hyperon. First write down the obvious strong interaction decays that you might expect, given its quantum numbers. Then check its lifetime and decay modes in the particle data book. Did you find the strong interaction decays you expected? If not, why not? What's the interaction responsible for its decay? Why?
6. **8 points:** Let's assume you observed the reaction e- proton -> electronneutrino + $l^- + l^- + X^{++}$ , where X++ refers to the double charged remnants of the inelastic collisison with the proton, and l refers to some lepton flavor. (Hint: Draw the appropriate second order weak interaction diagram and explain it.)
    a. What's the significance of this observation if l=electron ?
    b. Does your conclusion change when l=muon ?
7. **8 points:** $W^-$ bosons can be produced in pp or ppbar collisions via the parton process ubar + d -> W- . This is a charged weak interaction process, and only left-handed fermions and right-handed anti-fermions contribute.
    a. Sketch the expected polarization of the W- with respect to the direction of motion of the ubar and d quarks.
    b. Make qualitative comments about the difference, if any, in the W- polarization at the CERN SppbarS (ppbar at 630GeV center of mass), Tevatron (ppbar at 2TeV), and LHC (pp at 14TeV).
    c. How does your discussion change if the LHC was colliding p pbar instead of pp?
8. **20 points:** Isospin arguments can in some cases be used to relate amplitudes from weak processes, despite the fact that weak interactions violate isospin. In these cases, the flavor symmetry arguments relate the hadronization of final state quarks into hadrons, which conserves isospin. A very important example is the weak decay of B mesons into two pions.
    a. Write down the Isospin decomposition of the two pion final state. Why is I=1 forbiden in this case? You are thus left with only two transition amplitudes $\Delta I=1/2$ and 3/2.
    b. The figure below shows the two kinds of Feynman diagrams. The ones on the left are called "tree diagram" the ones on the right are called "penguin diagram".

   (a) Explain why tree diagrams are an admixture of ΔI=1/2 and 3/2 while the penguin diagram is pure ΔI=1/2 .
   (b) Why is there no penguin diagram for B+ to pi+pi0 ?

c. Armed with all of this information, show the amplitude relationship:

$$(1/\text{sqrt}(2))\ A^{+-} + A^{00} = A^{+0}$$

Where the charge superscript refers to the charges of the final state pions.



## FOR EXTRA CREDIT:

Extra problem 1: **10 points**

Show by drawing the relevant lowest order Feynman diagrams, that the Drell-Yan process pp -> e+e- + X can give information on the quark-sea distribution function. Also, show in the same manner that the prompt-photon process, ppbar -> photon + X can give information on the gluon distribution function. Note that there is also a diagram, at the same order, where the gluon distribution function does not matter (Draw it).

Extra problem 2: **26 points**

Suppose that the photon could couple at the same vertex to the muon and the electron. Then the muon would decay as mu- to e- photon at leading order. Calculate (in seconds) the lifetime of the muon in this case. To keep it simply, set the mass of the electron to zero. You can use the completeness relation H&M eq. 6.98. Also: (please!) to make grading easier, use momentum labels p, k, q, for the muon, electron, and photon respectively. (Note: You can think of this as an alternate problem to problem 1. In case you struggle too hard there.)