Homework # 6; due Thursday, October 14

Reading: Chapters 4 and 6 of Griffiths

22. A theorem attributed to C. N. Yang and L. D. Landau states that a vector particle (i.e., a particle with intrinsic angular momentum J=1) cannot decay into two photons. Prove the theorem based on the most general considerations of the quantum field theory (QFT). This sounds scary, but is really rather simple, and goes like this.

    The probability of the decay is proportional to the square of the *amplitude* of the decay process. This amplitude, in turn, has to be proportional to the first power of some quantity describing each of the particles participating in the process. For each of the photons, this quantity is conveniently chosen to be the polarization vector $\vec{\varepsilon}_1$ and $\vec{\varepsilon}_2$, respectively. Further, we can argue that some sort of polarization vector $\vec{V}$ (with three independent spatial components) can be employed to represent the initial vector particle in the decay amplitude. Finally, there is one more vector in the problem, $\vec{k} = \vec{k}_1 - \vec{k}_2$, representing the wave vectors (momenta) of the outgoing photons (in the rest frame of the decaying particle, most natural for this problem, $\vec{k}_1 = -\vec{k}_2$). All that is left for us to do is to build all possible scalar or pseudoscalar expressions, where each of the polarization vectors would enter once, and there are no a-priori restrictions on how many times the momentum may enter into the expression.

    Please do this, and show that each of the possible expressions for the amplitude is odd under the exchange of the two photons. Explain why such amplitudes have to be zero in the framework of conventional QFT, and comment on how this can be used to test this framework. For extra credit: dig up some experimental upper limit on the branching ratios of the Landau-Yang forbidden decays.

23. (**Corrected**)
    a. In lecture, we have discussed the amplitude corresponding to the decay of para-positronium into two photons. Write out the rotational invariant for such decay. Are there any symmetries violated by such a decay?
    b. Which symmetries would be violated in the two-photon decay of the ortho-positronium?

24. Look up the luminosity achieved most recently (perhaps, today) at a major collider of your choice. Compare this to the design specification for this machine. Which process is used to measure/monitor the luminosity?