

Physics 221C

Quantum Field Theory

Spring 2007

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ASSIGNMENT #3

Due: Friday, April 27, 5pm in TA's mailbox

1. If P and CP are not symmetries, the vertex iV^μ can have several additional terms:

$$\bar{u}' S_{\sigma\rho} u q_\nu \epsilon^{\mu\nu\sigma\rho}, \quad \bar{u}' \gamma^5 u (p + p')^\mu, \quad \bar{u}' \gamma^5 u (p - p')^\mu, \quad \bar{u}' \gamma^5 \gamma^\mu u, \quad \bar{u}' \gamma^5 S^{\mu\nu} u q_\nu.$$

Show, using current conservation, the on-shell conditions for the electrons, and gamma matrix identities, that the last four terms are either forbidden or can be rewritten in terms of the first one. Show that for a nonrelativistic electron in a constant magnetic field, the first interaction gives an electric dipole interaction.

2. a) In PS 6.3, how should h transform so as to make the interaction in PS 6.3(a) CP invariant? How should a transform so as to make the interaction in PS 6.3(c) CP invariant?

b) Suppose there is a real scalar ϕ with *both* kinds of interaction,

$$\mathcal{L} = \mathcal{L}_{\text{QED}} - \frac{1}{2} \partial_\mu \phi \partial^\mu \phi - \frac{1}{2} m^2 \phi^2 - \lambda \phi \bar{\psi} \psi - i\lambda' \phi \bar{\psi} \gamma^5 \psi.$$

What can you say about CP?

- c) Calculate the contribution to the electric dipole moment of the electron from a virtual ϕ .

d) It is conventional to define $\lambda = \tilde{\lambda} \cos \chi$, $\lambda' = \tilde{\lambda} \sin \chi$, parameterizing the ratio of coupling in terms of an angle χ . For $m = 1$ TeV and $\tilde{\lambda} = 1$, find the allowed values of χ .

3. Consider the two loop vertex correction in QED. Keep only the two graphs in which the incoming electron emits two soft photons which are both absorbed by the outgoing electron, as these are the most IR-divergent. In the limit that both virtual photon momenta are small, show that these graphs add to give the second term of an exponential series, as claimed in class.