1. Consider \( e^- e^- \) scattering in the nonrelativistic limit of electrodynamics. Show that the following Feynman diagram does not contribute:

![Feynman diagram]

2. a) Positronium states can be characterized by their \( J^{PC} \) quantum numbers. If \( L \) is the relative orbital angular momentum and \( S \) the spin of the state, argue that

\[
P = (-1)^{L+1}
\]
\[
C = (-1)^{L+S}
\]

b) The muon, \( \mu^- \), is just like the electron except that its mass is about 200 times greater than \( m_e \). The \( \mu^+ \mu^- \) analogue of positronium is known as “muonium.” Calculate the decay rate of the \( ^3S_1 \) state of muonium to \( e^+ e^- \).

3. Consider adding to the free theory

\[
\mathcal{L}_0 = \bar{e} (i \not{\partial} - m_e) e + \bar{\mu} (i \not{\partial} - m_\mu) \mu + \bar{\nu}_e (i \not{\partial}) \nu_e + \bar{\nu}_\mu (i \not{\partial}) \nu_\mu
\]

(where \( \nu_e \) and \( \nu_\mu \) are the electron neutrino and the muon neutrino, respectively) the interaction

\[
\mathcal{L}_{int} = -\frac{G_F}{\sqrt{2}} [\bar{\nu}_\mu \gamma^\mu (1 - \gamma_5) \mu] [\bar{e} \gamma_\mu (1 - \gamma_5) \nu_e]
\]

Neglecting the electron mass, show that the decay width for \( \mu \to e \bar{\nu}_e \nu_\mu \) is

\[
\Gamma = \frac{G_F^2 m_\mu^5}{192\pi^3}
\]