Physics 721, Fall 2023
Problem Set 9 Due Monday, November 13.

1. *"Meson-Nucleon" interactions*

Consider the theory defined by the Lagrangian density,

$$\mathcal{L} = \frac{1}{2}(\partial_\mu \phi)^2 - \frac{m^2}{2}\phi^2 + \overline{\psi}(i\partial\!\!\!/ - M)\psi - g\,\overline{\psi}(a + ib\gamma^5)\psi\phi,$$

where $\psi(x)$ is a Dirac spinor, ϕ is a real scalar, and the constants a, b and g are real.

a) At second order in g calculate the amplitude for scattering of ψ particles and antiparticles, $\psi + \overline{\psi} \to \psi + \overline{\psi}$. In other words, evaluate the $\mathcal{O}(g^2)$ contribution to

$$\langle p_a, r_a; p_b, r_b | (S-1) | p_A, r_A; p_B, r_B \rangle,$$

where (p_a, r_a) and (p_b, r_b) are the momenta and spins of the outgoing ψ and $\overline{\psi}$, respectively; and (p_A, r_A) and (p_B, r_B) are the momenta and spins of the ingoing ψ and $\overline{\psi}$, respectively.

Draw the $\mathcal{O}(g^2)$ Wick diagram contributing to this process. Write out all of the steps in the calculation; do not rely on Feynman rules.

b) Draw the Feynman diagrams corresponding to the terms in your calculation of part (a). Be sure to label the initial and final states.

What are the corresponding Feynman rules for this theory, *i.e.* the vertices, propagators and external lines which appear in the Feynman diagrams contributing to $\psi - \overline{\psi}$ scattering?