1. Consider the process $e + e^+ \rightarrow \mu + \mu^+$. Obtain an expression for the contribution to $M$ for any one of the fourth order realizations of this process. Your final expression can be in terms of spinor sandwiches. **Note:** There are a lot of possibilities and for a couple of choices you will not have the tools to evaluate it, but for most you should be able to use the results from your HW. Part of this question is to get you to identify what you can and cannot do.

$$M = i \left[ \frac{1}{(2\pi)^3} \frac{1}{2} \frac{1}{2} \frac{1}{2} \frac{1}{2} \left( \begin{array}{cc} q_1 & q_2 \\ \bar{u}(2) & u(1) \end{array} \right) \frac{1}{2} \frac{1}{2} \frac{1}{2} \frac{1}{2} \left( \begin{array}{cc} \bar{v}(4) & \bar{v}(3) \\ v(1) & v(2) \end{array} \right) \left( \begin{array}{cc} \frac{i}{2} & \frac{i}{2} \\ \frac{i}{2} & \frac{i}{2} \end{array} \right) \left( \begin{array}{cc} \frac{i}{2} & \frac{i}{2} \\ \frac{i}{2} & \frac{i}{2} \end{array} \right) \left( \begin{array}{cc} \frac{i}{2} & \frac{i}{2} \\ \frac{i}{2} & \frac{i}{2} \end{array} \right) \left( \begin{array}{cc} \frac{i}{2} & \frac{i}{2} \\ \frac{i}{2} & \frac{i}{2} \end{array} \right) \right] \div \left[ (2\pi)^3 \delta^3(p_1 + p_2 - p_3 - p_4) \right]$$

**Could also consider:**

But not:

This is allowed, but we don't have a Feynman rule for it yet!

Turn over for second problem!!
2) Show that the orthonormality and completeness relations for spinors imply that they satisfy the momentum-space Dirac equation, e.g. \((\gamma^\mu p_\mu - mc)u^{(1)} = 0\).

\[
\sum_s u^{(s)} \bar{u}^{(s)} = \gamma^\mu p_\mu + nc
\Rightarrow u^{(1)} \bar{u}^{(1)} + u^{(2)} \bar{u}^{(2)} = \gamma^\mu p_\mu + nc
\]

Multiply from right w/ \(u^{(1)}\)

\[
\bar{u}^{(1)} u^{(1)} + u^{(1)} \bar{u}^{(2)} u^{(1)} = \gamma^\mu p_\mu u^{(1)} + nc u^{(1)}
\]

Then use:

\[
\bar{u}^{(s)} u^{(s')} = 2nc \delta_{ss'}
\]

\[
\bar{u}^{(1)} u^{(1)} = 2nc
\]

\[
\bar{u}^{(2)} u^{(1)} = 0
\]

Giving:

\[
2nc u^{(1)} + 0 = \gamma^\mu p_\mu u^{(1)} + nc u^{(1)}
\]

\[
\left(\gamma^\mu p_\mu - nc\right) u^{(1)} = 0
\]