Short HW 4: **Cross Sections**

Course: Physics 165, *Introduction to Particle Physics* (2022)
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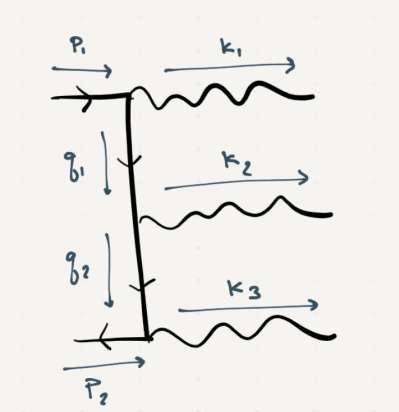
Due by: **Thursday**, April 21

1 Total Momentum Conservation for a $2 \to 3$ process

The following diagram is one contribution to the process $e^+e^- \to 3\gamma$:



Using the conservation of four-momentum at each vertex, show that the total four-momentum is conserved. That is, prove:

$$(p_1 + p_2)^\mu = (k_1 + k_2 + k_3)^\mu \ . \tag{1.1}$$

Hint: Start by writing the conservation of four-momentum at each vertex. Those are three equations with unspecified q_1^μ and q_2^μ. Use two equations to determine what these virtual momenta are, then plug them into the last equation to prove the above relation.

2 QED+μ

Here are the Feynman rules for "QED+μ," a theory of electrons, photons, and a second type of matter: muons, denoted μ. Muons have the same charge as electrons and so the strength of their vertex with the photon is exactly the same. What are the conserved charges in this theory?

Hint: as you can guess, electric charge is conserved. However, there's a bit more to it than that. For example, $\mu^- \to e^-\gamma$ conserves electric charge. When the muon mass m_μ is larger than the photon mass, then $\mu^- \to e^-\gamma$ is even kinematically allowed. However, this process cannot happen dynamically in the theory QED+μ.

Comment: Professor Tanedo's early Ph.D research focused on this process for theories with extra dimensions.[1]

[1] https://arxiv.org/abs/1004.2037