ISP220 Homework supplement #13
17 points

the paper part, to go along with the WebAssign part this week...

April 15, 2017
due in-class April 25

Your Name: ______________________________

Your Student Number: ______________________________

- This is the paper portion of Homework 13. There is also a WebAssign part.
- This paper portion of the set is due on **Tuesday, April 25 in class.** The WebAssign portion will be due as normal on Saturday night, April 22.
- If you have comments about your reasoning, say them.
- **STAPLE these pages**!!

Electron-Positron Annihilation

Under some conditions, electrons and positrons can caused to annihilate to produce a photon (subject to a wrinkle that I'll talk about). Here's the eventual reaction:

$$\bar{e} + e \rightarrow \gamma. \tag{1}$$

We're going to build up that reaction starting from the primitive diagram.

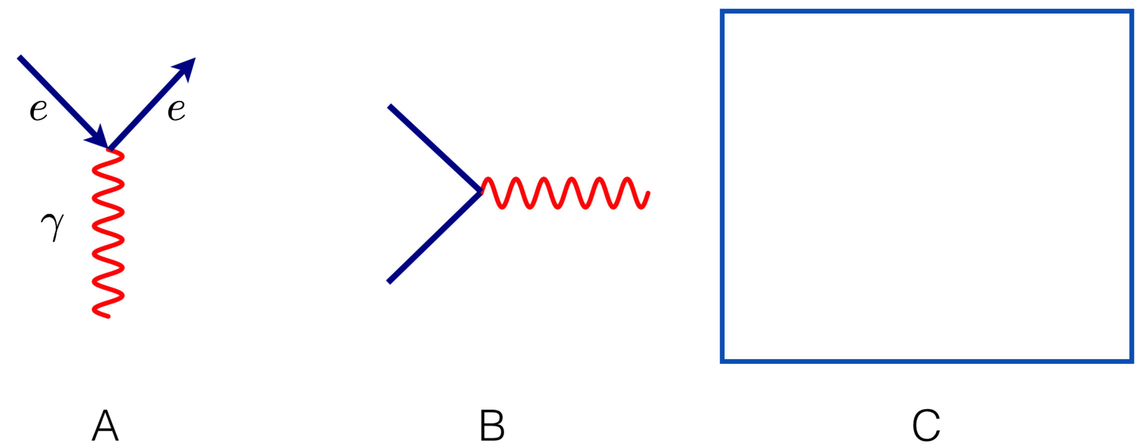

Figure 1: Creating the Feynman Diagram for electron-positron annihilation.

Figure 1 A shows your first primitive diagram for the fermion-photon interaction where here the general fermion is an electron.

1. (2 points) B is meant to be the counterclockwise rotation of A. In B, label the particles that result from that rotation of A and properly include the arrows.

2. (3 points) In the blue box fix any unphysical legs from B and show the proper Feynman Diagram for the eventual reaction...the annihilation as described in Eq. 1.

Compton Scattering

Remember the experiment done by Arthur Holly Compton that demonstrated the particle nature of light (X-rays) definitively. The reaction was:

$$\gamma + e \rightarrow \gamma + e \tag{2}$$

where the outgoing gamma was an X-ray of a
(1 points, circle your choice)

a. higher?

b. lower?

frequency than the initial gamma.

(2 points) In Fig. 2 complete the Feynman Diagram by referring to the Primitive Diagram and attaching the appropriate pieces. Treat the electron/positron arrows properly.

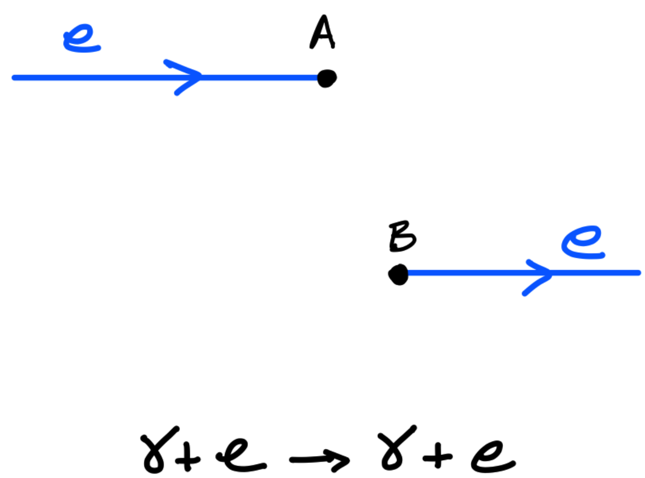

Figure 2: Complete the diagram for Compton Scattering.

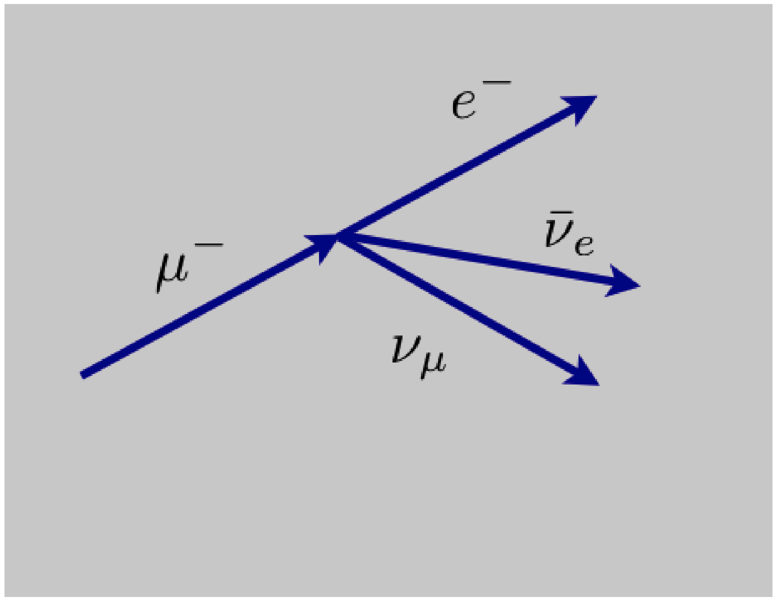

Figure 3: Decay of a muon (particle, not antiparticle) into an electron and two neutrinos.

Muon Decay

This problem involves the muon decay Feynman Diagram shown in Figure 3. A muon is a fermion that decays into 3 other fermions: an electron, a neutrino (with subscript e), and another kind of neutrino (with subscript μ). The electron and muon particles are negatively charged and the antiparticles are positively charged. For this problem, represent them with their charges as I've done, not with the bar over them. For the neutrinos, however, use the bar over the symbol to represent the antiparticle and pay attention to the fact that there are two kinds of neutrinos here and they have to be kept separate. Neutrinos are electrically neutral fermions.

So, here's the plan. The standard neutrino beams produced at accelerators consist overwhelmingly of muon neutrinos ν_μ (not antineutrinos). These neutrinos can scatter from electrons. What I want is to construct the Feynman Diagram for the process that I studied in the 1980's:

$$\nu_\mu + e \rightarrow \mu^- + \nu_e \tag{3}$$

Let's do this in the steps that I've outlined in lecture. Draw your answers below the questions.

4. (3 points) Pull the muon neutrino line from the final state into the initial state, push the initial muon line from the initial state into the final state, and bring the electron line from the final state into the initial state. Draw that diagram keeping track of the arrows. They will now not make sense. That is, you'll now have an electron leaving the initial state going backwards in time, etc.

5. (3 points) So, now fix the lines by using the Feynman trick of reversing the directions of the arrows and doing the appropriate thing to the particle-antiparticle nature of each adjusted leg.

There's **one more rule**. You can always change the all of the quanta in a diagram, all at once: all of the particles into antiparticles *and* all of the antiparticles into particles...everywhere, initial and final states together.

6. (3 points) Notice, that the previous diagram is not the reaction we want according to Eq. 3. It's also not practical: can you think of any positron targets? So turn it into the reaction we want...use the rule above and do it: Draw the final Feynman Diagram corresponding to Eq. 3.