PHYS-3203 Homework 9 Due 6 Apr 2022

This homework is due to `https://uwcloud.uwinnipeg.ca/s/QGK3eGfDRgND6sC` by 10:59PM on the due date. Your file(s) must be in PDF format; they may be black-and-white scans or photographs of hardcopies (all converted to PDF), PDF prepared by LaTeX, or PDF prepared with a word processor *using an equation editor*.

1. **Neutrino Recoil**

   When a muon-neutrino and an electron collide, the neutrino and electron can transform into an electron-neutrino and a muon. For reference, the electron and muon have masses m_e and m_μ respectively with $m_\mu > m_e$, and you may approximate both types of neutrino as being massless.

   (a) If the electron is initially at rest, what is the minimum initial neutrino energy required for this process to occur?

   (b) Suppose the electron is initially at rest and the final electron-neutrino moves off at an angle θ from the initial direction of motion of the muon-neutrino. If the initial muon-neutrino energy is E, find the energy of the electron-neutrino.

2. **Compton and Inverse Compton**

   Recall from our class notes that *Compton scattering* is the process in which a photon of initial energy E scatters from an electron (mass m) that is initially at rest (call the initial electron rest frame the "Compton frame"). The same process described in a reference frame where the electron is initially moving at speed u is called *inverse Compton scattering* (call this frame the "inverse Compton frame"). You may give your answers to this problem in natural units.

   (a) Find the total CM frame energy in terms of m and E.

   (b) The photon is initially moving in the $+z$ direction in the Compton frame. Consider the inverse Compton frame with the electron initially moving in the $-z$ direction at speed u. Using a Lorentz transformation, find the initial photon energy in the inverse Compton frame.

   (c) If the photon is initially moving in the $+z$ direction and scatters so that the final photon momentum is in the $-z$ direction, the final photon energy in the Compton frame is $mE/(m + 2E)$. Find the final photon energy in the inverse Compton frame as defined in the previous part. You may *not* use a Lorentz transformation. *Hint:* The final photon moves in the $-z$ direction in the inverse Compton frame as well.

   (d) Under what condition is the final photon energy greater than the initial photon energy in the inverse Compton frame? (These are your answers to the previous two parts.)