PHY312 - Homework 4

1. Consider a photon moving along the positive x-direction with energy 1×10^{-19} Joules (the Joule is the S.I unit of energy). Call this photon A. Imagine a second photon B of energy 2×10^{-19} Joules moving also along the x-direction.

   (a) What are the masses of photons A and B ?

   (b) What is the total energy of the two photons ?

   (c) What is the total momentum of the system of two photons ?

   (d) What is the total mass of the system of two photons ?

   (e) If we reverse the direction of photon B so that it is travelling in the negative x-direction what is now the energy, momentum and total mass of the combined system of two photons ?

   (f) Imagine now that photon B is replaced by a stationary electron of mass 9.1×10^{-31} kg. What is the total energy, momentum and mass of the photon A plus electron system ?

2. An electron of mass m is travelling with momentum p in the positive x-direction. It collides with its antipartner, a positron, which is travelling with the opposite momentum in the negative x-direction (like all antiparticles it has the same mass as its partner the electron).

   (a) What is the total energy of the system ?

   (b) What is the total momentum of the system ?

   (c) What is total mass of the system ?

   When they collide they annihilate into pure energy in the form of 2 photons. Each of these photons has the same energy. Using the principle of conservation of energy

   (d) What is the energy of each of these photons ?

   (e) What is the magnitude of their momenta ?

3. When x-rays are beamed at a slab of material they are scattered in a characteristic pattern and shifted in energy. The effect is called Compton scattering and its explanation in the early 1930's led to a Nobel Prize for the American physicist Arthur Compton. He assumed that the effect could be explained as the collision of a single x-ray photon with a stationary electron in an atom. We will consider the simplest case in which the photon's direction of motion is merely reversed after the collision and compute its new energy. After the collision the electron acquires a momentum too which we can also calculate. The tools that make this calculation possible are again the conservation of energy and momentum. Call E the photon energy and m the electron mass. After the collision let the photon move (in the negative x-direction now) with energy E' while the electron moves in the positive x-direction with momentum p.

(a) Write down 2 equations expressing the conservation of energy and momentum for ths system.

(b) Eliminate the energy E' between these two equations. You should have an equation now between p and the (known) quantities E and m. Try and simplify this to get an explicit equation for p.

(c) If we use x-rays with photon energy equal to 2 electron rest masses what is the momentum p (in terms of m)?