ID #33
Problem Set 6
Physics 202
February 5, 2018

1. (a) Since the rest mass is $4\,\text{GeV}/{c_0}^2$, as shown in part b, if the momentum is $4\,\text{GeV}/c_0$, then

$$E^2 = p^2 + m^2 = \sqrt{32} \approx 5.66\,\text{GeV}$$

   (b) The rest mass is given by

$$m^2 = 5^2 - 4^2 = 9 \implies m/c^2 = 4\,\text{GeV}/{c_0}^2$$

   (c) The difference in momenta is $1\,\text{GeV}/c_0$. Then

$$p = \gamma m_0 v = \frac{m_0 v}{\sqrt{1-(v/c)^2}} \implies v = \frac{cp}{\sqrt{m^2+p^2}} = \frac{c}{\sqrt{17}}$$

2. (a) The total energy of the electron after the collision is

$$E_e^2 = (m_e/c^2)^2 + (p_e/c)^2$$

However, the momentum must have come from the charged particle, so

$$E_i - E_f = p_e/c$$

I'm sorry, I can't figure out how to go on from here. The momentum and rest mass equations don't make sense for a massless particle, so I really don't know how to use the momentum of the electron to get the trajectory of the photon.

3. (a) The direction of particle 3 is given by

$$\theta = \arctan\left(\frac{3c/5}{4c/5}\right) = \arctan(3/4) \approx 36.87^\circ$$

The momenta of the first two particles are:

$$p_1 = \gamma m_0 v_1 = \frac{m_0(4c/5)}{\sqrt{1-(4/5)^2}} = \frac{4cm_0}{3}$$

$$p_2 = \gamma m_0 v_2 = \frac{m_0(3c/5)}{\sqrt{1-(3/5)^2}} = \frac{3cm_0}{4}$$

Then the 3rd particle's momentum is

$$p_3^2 = p_1^2 + p_2^2 \implies p_3 = 1.53cm_0$$

Then

$$1.53cm_0 = \frac{m_0 v_3}{\sqrt{1-(v/c)^2}} \implies v_3 \approx 0.837c \tag{1}$$

   (b) Each particle's energy is given by

$$E_n = \sqrt{(m_0c^2)^2 + \left(\frac{m_0 v_n}{\sqrt{1-(v_n/c)^2}}\right)^2}$$

Therefore, letting $M_0 = 1$,

$$c^2 = \sqrt{(m_0c^2)^2 + \left(\frac{m_0 v_1}{\sqrt{1-(v_1/c)^2}}\right)^2} + \sqrt{(m_0c^2)^2 + \left(\frac{m_0 v_2}{\sqrt{1-(v_2/c)^2}}\right)^2} + \sqrt{(m_0c^2)^2 + \left(\frac{m_0 v_3}{\sqrt{1-(v_3/c)^2}}\right)^2}$$

$m_0 = 0.211M_0$, so $M_0/m_0 = 4.73$.