Physics 2710 (Schroeder) Name ______________________________
fall 2012

Problem Set 3

(due Friday, September 21, 5:00 p.m.)

1. (Moore, Problems R8S.8 and R8S.9, page 151.) Two particles of equal mass are observed (in the Home Frame) to move along the x axis in opposite directions, both with speed 0.60. The particles collide and stick together, becoming one big particle which remains at rest in the Home Frame. Now imagine observing these events from an Other Frame that moves at $\beta = 0.60$ in the $+x$ direction with respect to the Home Frame.

   (a) Find the velocities of both particles in the Other Frame, as well as the final velocity of the composite particle.

   (b) Show that the total Newtonian momentum of the system of two particles is conserved in the Home Frame, but not in the Other Frame.

2. (Moore, Problem R9B.7, page 169.) An object is observed in a certain inertial frame to have a four-momentum vector whose components are $[P_t, P_x, P_y, P_z] = [18\text{ kg}, 9\text{ kg}, 15\text{ kg}, 1\text{ kg}]$. Find the object's (a) velocity (vector); (b) speed; (c) mass; (d) three-momentum magnitude (p); (e) kinetic energy.

3. (Moore, Problem R9B.9, page 169.) An object's four-momentum in the Home Frame is $[P_t, P_x, P_y, P_z] = [5.0\text{ kg}, -3.0\text{ kg}, 0, 0]$. What is its four-momentum in an Other Frame that moves in the $+x$ direction with speed 0.80 with respect to the Home Frame?

4. By what fraction does the mass of a cup of water increase when you raise its temperature from 0°C to 100°?

5. Travel to the stars within a human lifetime would require relativistic speeds. Never mind the spaceship and supplies; let's just contemplate accelerating an astronaut to high speed.

   (a) Calculate the energy required, in joules, to accelerate a 70-kg astronaut from rest to a speed of 1/2.

   (b) Convert your answer to kilowatt-hours. (Recall that a watt-second is a joule, "kilo" means 1000, and there are 3600 seconds in an hour.)

   (c) Utah residential customers currently pay about eight cents per kilowatt-hour for electrical energy, but to be generous, let's imagine that we can obtain a quantity discount and buy the energy for only two cents per kwh. If this electrical energy can be converted to kinetic energy with 100% efficiency, what is the cost of accelerating our astronaut to a speed of 1/2?

6. (Moore, Problem R10S.8, page 189.) A pion (an unstable particle with mass 140 MeV) decays into a muon (mass 106 MeV) and a neutrino (which is essentially massless, like

a photon). If the pion is initially at rest, find the speed of the emitted muon and the energy of the emitted neutrino.

7. (Moore, Problem R10S.9, page 189.) A photon with energy E_0 scatters off an electron (mass m) that is initially at rest. The photon bounces straight back with energy E, while the electron recoils forward. Find a formula for E in terms of E_0 and m. (This process is called *Compton scattering*.)

8. If they have enough energy, an electron and a positron (same mass as the electron but opposite charge) can annihilate each other to form a relatively heavy particle called the Z, with a mass of 91 GeV.

   (a) Suppose we wish to form a Z particle by colliding a fast-moving electron into a positron that is at rest. In order for the collision to conserve both energy and momentum, how much energy must the electron have?

   (b) Can you suggest a more economical way to create Z particles? Explain in detail. (Hint: The Z particle ends up with less energy if it also has less momentum.)