Physics 252 – **Modern Physics**

Homework Assignment #10

Due Friday, April 20, 2007 at the beginning of class.

Reading: Born, III.1, V.14-15, chapter VI; Fowler, the relativity lectures

1. Muons are created when cosmic rays scatter off the upper atmosphere. Their half-life is 2.2×10^{-6} seconds. To simplify the problem, assume that all are created with the same velocity v, and that they don't slow down before decaying. Say they move an average of $5000\,m$ before decaying. What is v? Hint: any answer greater than the speed of light is wrong!

2. To test special relativity, one can send an clock in a plane around the world at a constant velocity, and then compare with a clock left behind. Say the plane is going around the world at the equator at a speed of $300\,m/s$ westward relative to the earth. Compute the difference in elapsed time measured by the two clocks. Say the speed of light were instead the speed of sound ($\approx 800\,mph$). What would the time difference be in this case?

3. Say we have a garage $5\,m$ long made of glass. A car traveling close to the speed of light drives into the garage and crashes into the back wall. The car measures $6\,m$ long when at rest, but because of length contraction, it looks shorter to us on the ground. Is it possible for us to take a picture so that we see the entire car in the garage before it crashes? If so, calculate the speed at which the car needs to be traveling. What is the length of the garage according to someone in the car?

4. Consider two events, at spacetime points $(\vec{x_1}, t)$ and $(\vec{x_2}, t)$. Show that the interval

$$\Delta = c^2(t_2 - t_1)^2 - |\vec{x}_1 - \vec{x}_2|^2$$

   is the same in any frame, i.e.

$$\Delta = c^2(t_2' - t_1')^2 - |\vec{x_1'} - \vec{x_2'}|^2$$

5. Newton's second law in the form $\vec{F} = d\vec{p}/dt$ still holds in any relativistic system. If the force and the velocity are both in the x direc tion, show that $F_x = \gamma^3 m a_x$.

6. Consider the experiment discussed in class and in the book, where a ball of mass m moving at speed v hits an identical ball, and the two stick together, moving off at a velocity u. Change to a frame where the final velocity is 0. What are the initial velocities of the balls in this new frame, in terms of v? (**Hint**: in the non-relativistic limit they are $\pm v/2$.) In this new frame, how much kinetic energy is converted into the mass of the blob?