PHYS-3301 Homework 4 Due 10 Oct 2012

This homework is due in the dropbox outside 2L26 by 11:59PM on the due date. If you wish to turn it in ahead of time, you may email a PDF or give a hardcopy to Dr. Frey.

1. **Invariance of Light Speed**

   In this question, we'll show that the speed of light is invariant, no matter the direction of the velocity. (Of course, our derivation of the Lorentz transformations showed this for light moving along the relative motion of two frames.) Start in the S frame, where a light beam leaves the origin at time $t = 0$ and reaches point $\vec{x} = (x_0, y_0, 0)$ at time $t = \sqrt{x_0^2 + y_0^2}/c$, hitting a detector there. Now consider a frame S' moving at speed v relative to S along the x axis.

   (a) At what coordinates t', x', y', z' does the light hit the detector? Write your answer in terms of c, x_0, y_0, and v.

   (b) Find the components of the light's velocity in the S' frame by dividing x'/t', etc. What is the speed of light in S'?

   (c) Why don't we need to think about a component of motion along the z axis to get a general proof of the invariance of the speed of light?

2. **Pairs of Events***From Barton 4.2 & 3*

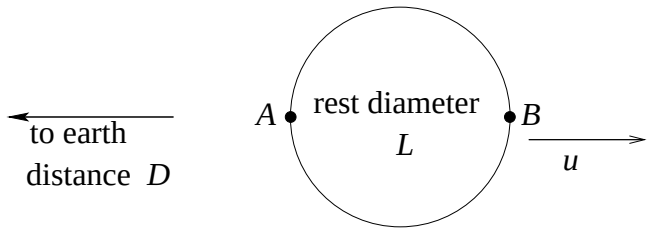
   In this problem, frames S and S' are in standard configuration with relative speed v. Use the Lorentz transformations to answer the following questions.

   (a) In the S frame, two events happen at the same place but a time interval $\Delta t = T$ apart. In S', they occur a time interval $\Delta t' = 3T/2$ apart; what space interval $\Delta x'$ separates the events in S'? What does the sign (positive or negative) of $\Delta x'$ mean?

   (b) *Almost Barton 4.3* In S, two events happen at the same time but separated in space by a distance $\Delta x = L$. In S', they occur a distance $\Delta x' = 3L/2$ apart; what time interval $\Delta t'$ separates the events in S'? What does the sign of $\Delta t'$ mean?

3. **A Moving Galaxy** *Rephrased from Barton 4.8*

   Consider the galaxy in the figure below. It moves away from us (at earth) with speed u, and its diameter is lined up along the direction of motion. In its own rest frame, the diameter of the galaxy is L, and its center is distance $D \gg L$ from the earth. At some (different in some reference frames) times, stars explode at points A and B, which are the points closest and farthest from earth respectively. Light from the explosions reaches us at the same time. What is the time interval between the explosions measured in the galaxy's rest frame? In the earth's rest frame?



   Hint: As the book says, you don't need all the information all the time. Also, it pays to choose your reference frame wisely.