Problem Set 5

1 Readings

Read up on special relativity. Two documents are linked to from our website. They are both useful. See syllabus for additional reading assignments.

2 Problems

1. Thought Problems:

   (a) We learned in class that no information can travel faster than the speed of light. Describe something that does travel faster than the speed of light, and its ok by relativity because it doesn't carry any information

   (b) A sphere is moving at 90% the speed of light perpendicularly to your line of sight. In your reference frame what shape does it have?

   (c) Consider that same sphere. What shape does it look like to you? (different from the previous answer because light takes a finite time to reach your eyes as well)

2. A person standing on a train moving with speed v (with respect to the ground) releases a ball from rest at a height h above the floor. The ball falls straight down and hits the floor at a time $t = (2h/g)^{1/2}$, where g is the gravitational acceleration. Sketch the trajectory that an observer at rest on the ground measures. (Assume that one side of the train is made of transparent material.) How do you reconcile, quantitatively, the different trajectories with the fact that Newton's second law, $\vec{F} = m\vec{a}$, is supposed to work equally well in both of these inertial frames.

3. A bullet is fired with velocity $\vec{u'}$ in the $x'y'$ plane of a moving frame S' and at an angle θ' with respect to x'. Frame S' moves with velocity v with respect to the laboratory frame S along the x axis. Find the angle the velocity vector of the bullet makes with the x axis of the laboratory frame. What if the bullet is a photon?

4. A circus company advertises its arrival in Cambridge, Massachusetts with big headlines in local newspapers describing the first show ever that is plausible to beat the speed of light. The spectacle is described as follows. First, they set up a long enough train that travels at a velocity v ($v < c$) with respect to the audience. Then, a number of small carts are added one on top of the other and on top of the train. Each cart moves at velocity v wth respect to the previous one and in the same direction. The company claims to put as many carts as it takes so that the speed of the final cart (as seen by the audience) on top of this pyramid to exceed the speed of light.

   Will they be able to succeed? Explain.

   Find the speed of the nth cart.

5. Consider the admittedly unrealistic situation of a man carrying horizontally a 20-foot pole and wanting it to get into a 9-foot garage. Our unrealistic man can run at $v = 0.866c$ (or $\gamma = 2$). There is a massive block on concrete at the end of the garage. In the rest frame of the garage, the pole is contracted to 10 feet long. This seems insufficient for the pole to fit into the garage. However, the front of the pole does hit the concrete block and never leaves the garage. Use the fact that no information-bearing signal can travel faster than c to answer the question of whether the back of the pole enters the garage.

6. Can a person, in principle, travel from Earth to the galactic center in a normal lifetime? Explain, using either time-dilation or length-contraction arguments. What constant velocity would be needed to make the trip in 30 years?

7. A particle of rest mass m_1 and velocity v_1 collides with a stationary particle of rest mass m_2 and is absorbed by it. What is the velocity and the rest mass of the final compound system?