Homework Problems for Special Relativity

First Assignment

1. In a certain particle accelerator experiment, two subatomic particles A and B are observed to fly away in opposite directions from a particle decay. Particle A is observed to travel with a speed of 0.6c relative to the laboratory, and particle B is observed to travel with a speed of 0.9c. Here c is the speed of light. According to the Galilean velocity transformations, what would be the speed of particle B in an inertial reference frame that is attached to particle A? (Try letting the reference frame of A be the primed frame and the laboratory be the unprimed frame.)

2. A person in an elevator drops a ball of mass m from rest a height h above the floor of the elevator. The elevator is moving with a constant speed β in the downward direction relative to the rest of the building.
    a. In the reference frame of the building, how far does the ball fall before it touches the floor of the elevator? (The answer is not h.)
    b. What is the initial velocity of the ball in the reference frame of the building? (The answer is not zero.)
    c. Use the law of conservation of energy in the reference frame of the building to compute the speed of the ball just before it touches the floor of the elevator.
    d. Use the Galilean transformations to find the velocity of the ball just before it hits the floor in the reference frame of the elevator.
    e. Show that, having assumed conservation of energy in the reference frame of the building, we also conserve energy for the ball in the reference frame of the elevator.

3. Suppose that you are in an inertial reference frame in empty space with a clock, a telescope, and a powerful strobe light. A friend is sitting in the same reference frame a very large distance away. At precisely noon, you set off your strobe light and begin looking through your telescope. Exactly 30 seconds later you see the face of your friend's clock briefly light up due to your strobe flash. Assuming that your friend's

clock is synchronized with yours, what do you see on the face of the other clock and how far away is it? Explain your reasoning.

4. Draw a spacetime diagram and show on it the worldlines of the following particles.
   a. Particle A passes x=0 at t=0 while traveling at a constant velocity of +3/5.
   b. Particle B passes the point x=3s at t=0 while traveling at a constant velocity of -1/4.
   c. Particle C passes the point x=0 at t=2s traveling at a velocity of +1/2 but then is decelerates (beginning at t=2s) uniformly until it comes to rest. It then just sits there.
   d. Particle D starts from rest at x=0 and t=-2s and accelerates uniformly in the positive direction until it crashes into a wall at x=5s at t=4s. It then remains at rest.
   e. A flash of light E is emitted in the negative x direction from x= 5s at t=1s.
   f. A flash of light F is emitted in the positive x direction from x=-2s at t=0.

5. Imagine a spaceship in deep space is approaching a space station at a constant speed of v=3/4. Let the space station define the point x=0 in its own reference frame. At the time t=0 the space ship is 16 light-hours away from the space station. Event A is the emission of a laser pulse from the ship to the space station telling the station that the ship wishes to dock. Event B is the reception of the signal by the station and event C is the emission, after a 0.5 hour delay, of a return laser pulse telling the ship it is ok to dock. Event D is the reception of the permission signal by the ship. At this moment the ship begins to decelerate. According to clocks in the station, the ship arrives at the docking port (event E) 6.0 hours after event D.
   a. Make a spacetime diagram (mark the axies in hours) that shows the worldlines of the station, the ship, and the two laser pulses. Label events A through E.
   b. Compute the magnitude of the average acceleration of the ship between events D and E in SR units (s^{-1}) and in gs ($1g=9.8m/s^2$).

6. Imagine two clocks, P an Q. Both clocks leave the spatial origin of an inertial reference frame S at t=0; call this the origin event O. Both clocks move along the +x axis with P traveling at 4/5 and Q traveling at 1/5. After some time P slows to a stop and then accelerates back toward the origin until it smashes into Q. This collision is event A.
    a. Draw a qualitatively accurate spacetime diagram of the situation described above. Show the worldlines of P and Q. Indicate the events O and A.
    b. Assume P and Q were synchronized with a clock at rest at the origin at event O. Will P and Q read the same time when they collide? Explain.
    c. An observer R in S measures the time between O and A by using synchronized clocks at rest in S at the locations of events O and A. Who among P, Q, and R measures the
        i. Proper time between O and A?
        ii. Coordinate time between O and A?
        iii. Spacetime interval between O and A?

7. Anastasia is a passenger on a train moving at constant velocity. She synchronizes her watch with the station clock as she passes through the Chicago station and then compares her watch to the Milwaukee station clock when they pass that later in the day. If we consider her passing the two clocks to be events A and B, does her watch measure the proper time, coordinate time, or the spacetime interval between A and B? Assume the ground is an inertial reference frame. If one subtracts the reading of the Chicago clock at event A from the Milwaukee clock at event B, what kind of time interval does one get? Justify your answers.