Homework Set #3

Due Date: Wednesday July 17th

1) Lorentz Contraction
A meter stick lies along the x' axis and at rest in the rocket frame. Show that an observer in the laboratory frame will conclude that the meter stick is Lorentz contracted if they measure how long it take the meter stick to pass a point in their reference frame and multiples the result by the relative velocity of the two frames.

2) Time dilation
Two events occur at the same place but at different times in the rocket frame. Show that an observer in the laboratory frame will conclude that the time between the two events has been dilated if he measures the distance between them in the laboratory frame and divides this distance by the relative velocity of the two frames.

3) Mass Conversion Examples

1 How much mass does a 100-W bulb dissipate in one year?

2 The US generates $\sim 310^{12}$ kWh of energy/year. How much mass is this equivalent to ?

3 A student pedaling a bicycle all out produces about 0.5 horsepower of useful power. The human body is about 25% efficient. How long will our student have to ride (all out) to lose one pound by the conversion of mass to energy ? How do people loose weight at the gym?

4 About 1.4 kW of sunlight falls on 1 m^2 of earths surface (ignoring the effects of the atmosphere). How much mass does the sun radiate as light in one second? How much of the suns mass reaches the earth per year in the form of light?

5 Two trains, each weighing 10^8 kg, traveling in opposite directions at 100 mph collide and come to rest. How much is the rest mass of the collision debris increased immediately after the collision?

4) Relativistic Proton Collisions
Proton A collides elastically with proton B, which is at rest. The outcome of each individual collision cannot be predicted. However, occasionally there is a "symmetric collision" in which the two protons come off with identical speeds along paths that make identical angles $\alpha_A = \alpha_B = \alpha/2$ with the forward direction. What is this angle of deflection in a symmetric collision? For Newtonian mechanics the total angle of separation is always 90^o. (Review your solution to problem 4 in homework # 2.) You will see that this angle will be less than 90^o for a relativistic impact. This is one of the most decisive predictions that confirms relativity. The difference between the separation angle from 90^o provides a useful measure of the departure from Newtonian mechanics. How high must the velocity of proton A be before the separation angle deviates from 90^o by as much as 1/100 of a radian? Compare your answer to problem 4 of homework #1.

(Hint 1: It simplifies the analysis to use a frame of reference in which the collision is symmetric.)
(Hint 2: You need to calculate the angle between to **velocities** in the lab frame.)