Physics 200 Problem Set 1

Problem 1

a) Approximately how fast would a city bus have to drive for an observer standing beside the road to measure the bus to be shorter than its actual length by the size of an atom?

b) A jet airplane flies from Vancouver to Toronto and back. Estimate the time difference between a clock that went on the plane and a clock that stayed in Vancouver, if the clocks were originally synchronized.

Note: for these questions, you only need to work out the order of magnitude of the result (e.g. $10^4 m/s$ or $10^1 m/s$). Since the velocity will be relatively small compared with c, it is useful to use the binomial approximation for γ, discussed in the text. A simple way to understand the binomial approximation is the following: we have $\gamma = f(v^2/c^2)$ where $f(x) = (1-x)^{-1/2}$. If we zoom in to the region near $x = 0$, the function f looks more and more like a line. So for very small v/c it is a good approximation to replace the function $f(x)$ by a line with the same value at $x = 0$ and the same slope, $f_{approx}(x) = 1 + x/2$ (you can check that $f(0) = 1$ and $f'(0) = 1/2$). Thus, if v/c is very small, then we have $\gamma = f(v^2/c^2) \approx f_{approx}(v^2/c^2) = 1 + v^2/(2c^2)$.

Problem 2

Miley Cyrus, age 18, is worried that Justin Bieber, age 17, is getting more attention from the media because he is younger than Miley. So Miley decides to fly to Alpha Centauri, 4.5 light years away, and back, to take advantage of the effects of time dilation. She makes her trip at a constant velocity, and when she returns, she is delighted to find that she is now the same age as Justin. How old are the two teen stars when Miley returns (assume that Miley is exactly one year older when she leaves)?

Problem 3

A train of length 300m observes another train on a parallel track coming towards it at $v = \sqrt{3/4}c$. The other train appears (i.e. is measured by the first train) to have length 300m also. In the reference frame of the second train, how long does it take for the two trains to pass each other (i.e. what is time between when the fronts align and when the backs align)? *Hint: be careful*