Physics 3710 – Problem Set #3

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1. GPS satellites orbit the Earth with a speed of about 4 km/s.
(a) It takes a time $\Delta t_E$ for the satellite to make one orbit according to the Earth. How much time, $\Delta t_S$, does it take on board the satellite? Express your answer in terms of $\Delta t_E$ and $\gamma$.
(b) Express the difference, $\text{diff} = \Delta T_E - \Delta T_S$, in terms of $\Delta t_E$ and $\gamma$.
(c) Using the binomial expansion, show that, for small $\beta$, $1 - \frac{1}{\gamma} \approx \frac{1}{2} \beta^2$.
(d) Relative to an observer fixed to Earth, what is $\beta$ for the satellite?
(e) Suppose $\Delta t_E = 12$ h exactly. What is the value of $\text{diff}$ in seconds?
(f) The smallest error in position that an uncorrected GPS system would produce in one orbit is $c \cdot \text{diff}$. How many meters is $c \cdot \text{diff}$? If the target error is less than 10 m, does the GPS system have to take special relativity into account?

2. As seen from Earth, a particle created at an altitude of 25 km (event A) decays just as it reaches Earth’s surface (event B), 100 $\mu$s after creation.
(a) What is the lifetime in the Earth frame in units of km?
(b) What is the dimensionless speed of the particle re Earth?
(c) What is $\gamma$ for the particle’s frame re Earth?
(d) What is the lifetime of the particle in its own rest frame in km?
(e) How far is Earth’s surface from the particle in the particle’s rest frame at the moment of creation?