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## 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,  $diff = \Delta T_E - \Delta T_S$ , 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  $diff$  in seconds?
  - (f) The smallest error in position that an uncorrected GPS system would produce in one orbit is  $c \cdot diff$  . How many meters is  $c \cdot diff$  ? 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?