Name ______________________________ Date ______________

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Quiz 1: Relativity

$$\Delta t' = \gamma \Delta t_p \quad L' = \frac{L_p}{\gamma} \quad c = 3 \cdot 10^8\,\mathrm{m/s} \quad \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \quad v_{\mathrm{obj}} = \frac{v + v'_{\mathrm{obj}}}{1 + \frac{vv'_{\mathrm{obj}}}{c^2}}$$

$$v'_{\mathrm{obj}} = \frac{v_{\mathrm{obj}} - v}{1 - \frac{vv_{\mathrm{obj}}}{c^2}} \quad x' = \gamma\left(x - vt\right) \quad t' = \gamma\left(t - \frac{vx}{c^2}\right)$$

1. An airplane 10.0 m long is flying at 300 m/s. How much shorter will this airplane appear to be to an observer on the ground?

- ■ 5×10^{-6} m
- □ 2×10^{-3} m
- □ 0.1 m
- □ 5 m

The observer on the ground is in motion relative to the airplane at velocity $v = 300\,\mathrm{m/s}$. The airplane will appear shorter to this observer by a factor γ:

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{1}{\sqrt{1 - 10^{-12}}} \approx 1 + 10^{-12} \tag{1}$$

The length appears to the observer on the ground as the rest length of the the airplane $L = 10.0\,\mathrm{m}$ divided by the factor γ

$$L' = \frac{L}{\gamma} = L\sqrt{1 - v^2/c^2} = 10.0\sqrt{1 - 10^{-12}} \approx 5 \times 10^{-6}\,\mathrm{m} \tag{2}$$

2. A crew watches a movie that is two hours long in a space-craft that is moving at high speed through space. Will an Earthbound observer, who is watching the movie through a powerful telescope, measure the duration of the movie to be:

- ■ Longer than two hours.
- □ Shorter than two hours.
- □ Equal to two hours.
- □ I'd tell you, but that would violate the temporal prime directive.

The earthbound observer is in motion relative to the movie, which has a proper length of two hours, so the earthbound observer will see a dilated (longer) time interval.

3. Which one of these things can two observers in different frames **not** agree on?

- □ Their relative speed of motion with respect to each other.
- □ The speed of light c.
- □ The simultaneity of two events taking place at the same position and same time in some frame.
- ■ The distance between two points that remain fixed in one of their frames.

Observers always agree on their relative speed and the speed of light. Events taking place at the same time ($\Delta t = 0$) and position ($\Delta x = 0$) in one reference frame will also be simultaneous in any other non-accelerating reference frame, since this implies

$$\Delta t' = \gamma \left(\Delta t - \frac{v \Delta x}{c^2} \right) = 0 \tag{3}$$

Only the last option remains. If the two observers are in relative motion, they will experience length contraction, and cannot agree on the distance between two points in general.

4. The period of a pendulum is measured to be 3.00 in its own reference frame. What is the period as measured by an observer moving at a speed of $0.950c$ with respect to the pendulum?

- □ 6.00 sec
- □ 13.4 sec
- □ 0.938 sec
- ■ 9.61 sec

We need only apply time dilation to the pendulum's period. The observer at rest with respect to the pendulum sees a period of $T = 3.00\,\mathrm{s}$, the moving observer must see

$$T' = \gamma T = \frac{T}{\sqrt{1 - v^2/c^2}} \approx 9.61\,\mathrm{s} \tag{4}$$