Name ______________________________ Date ______________

PH 102 Quiz 1 SOLUTION: Relativity and so forth

$$\Delta t' = \gamma \Delta t_p \qquad L' = \frac{L_p}{\gamma} = L_p\sqrt{1-\frac{v^2}{c^2}} \qquad c = 3.00\times 10^8\,\mathrm{m/s} \qquad \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

1. An astronaut traveling at $v=0.80c$ taps her foot 3.0 times per second. What is the frequency of taps determined by an observer on earth? (*Hint: be careful about the difference between time and frequency!*)

- ◯ 5.0 taps/sec
- ◯ 6.7 taps/sec
- ⊗ 1.8 taps/sec
- ◯ 3.0 taps/sec

The 'proper time' Δt_p is that measured by the astronaut herself, which is 1/3 of a second between taps (so that there are 3 taps per second). The time interval *between taps* measured on earth is dilated (longer), so there are *less* taps per second. For the astronaut:

$$\Delta t_p = \frac{1\,\mathrm{s}}{3\,\mathrm{taps}}$$

On earth, we measure the dilated time:

$$\Delta t' = \gamma \Delta t_p = \frac{1}{\sqrt{1-\frac{0.8^2c^2}{c^2}}}\cdot\left(\frac{1\,\mathrm{s}}{3\,\mathrm{taps}}\right) = \frac{1}{\sqrt{1-0.8^2}}\cdot\left(\frac{1\,\mathrm{s}}{3\,\mathrm{taps}}\right) \approx \frac{0.56\,\mathrm{s}}{\mathrm{tap}} = \frac{1\,\mathrm{s}}{1.8\,\mathrm{taps}}$$

2. A spaceship moves away from earth at high speed. How do experimenters on earth measure a clock in the spaceship to be running? How do those in the spaceship measure a clock on earth to be running?

- ◯ slow; fast
- ⊗ slow; slow
- ◯ fast; slow
- ◯ fast; fast

The time-dilation effect is symmetric, so observers in each frame measure a clock in the other to be running slow. Put another way, the *relative* velocity of the earth and the ship is the same no matter who you ask – each says the other is moving with some speed v, and they are sitting still. Therefore, the dilation effect is the same in both cases.

3. If you are moving in a spaceship at high speed relative to the earth, would you notice a difference in your pulse rate? In the pulse rate of the people back on earth?

⊗ no; yes
◯ no; no
◯ yes; no
◯ yes; yes

There is no relative speed between you and your own pulse, since you are in the same reference frame, so there is no difference in your pulse rate (possible space-travel-related anxieties aside). There is a relative velocity between you and the people back on earth, however, so you would find their pulse rate *slower* than normal. Similarly, they would find *your* pulse rate slower than normal, since you are moving relative to them. Relativistic effects are always attributed to the other party – you are always at rest in your own reference frame.

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

The proper time is that measured by in the reference frame of the pendulum itself, $\Delta t_p = 3.00\,\text{sec}$. The moving observer has to observe a *longer* period for the pendulum, since from the observer's point of view, the pendulum is moving relative to it. Observers always perceive clocks moving relative to them as running slow. The factor between the two times is just γ:

$$\Delta t' = \gamma \Delta t_p = \frac{3.0\,\text{sec}}{\sqrt{1-\frac{0.95^2c^2}{c^2}}} = \frac{3.0\,\text{sec}}{\sqrt{1-0.95^2}} \approx 9.61\,\text{sec}$$

5. The Stanford Linear Accelerator (SLAC) can accelerate electrons to velocities very close to the speed of light (up to about $0.99999999995c$ or so). If an electron travels the 3 km length of the accelerator at $v = 0.999c$, how long is the accelerator from the *electron's* reference frame?

⊗ 134 m
◯ 67.1 km
◯ 94.9 m
◯ 300 m

The electron in its own reference frame sees the *accelerator* moving toward it at $0.999c$, and sees a contracted length:

$$L = \frac{L_p}{\gamma} = 3\,\text{km} \cdot \sqrt{1-\frac{0.999^2c^2}{c^2}} = 3\,\text{km} \cdot \sqrt{1-0.999^2} = 0.134\,\text{km} = 134\,\text{m}$$