Theory of Relativity – Final Quiz
July 11, 2012

Name:____

Below are short questions and problems. Answer to the best of your ability. All equations and constants you need are on a separate sheet.

VERY short answers. Each worth 1 point.

1. According to special relativity, if a ship moving at $v = .99999c$ fires a laser beam what will a stationary observer measure the laser beam's speed to be? What does the ship measure the laser beam's speed to be?

2. The equation $E = mc^2$ is often given in popular descriptions of Special Relativity. Is it correct for moving masses?

3. You and a friend are moving at a speed of $100 m/s$ relative to one another. According to special relativity, what two speed measurements will you both agree on? That is you each make a speed measurement, and later compare to find the values to be the same.

4. Inertial observers in Newton's theory are related by what type of coordinate transformation (the name, although feel free to write the equations)? What coordinate transformation relates inertial observers in special relativity?

5. Suppose I am in an inertial frame and you move at a speed $v = 10m/s$ relative to me. Are you an inertial observer?

6. List 3 ways our life would be different if the speed of light were $80km/hour$.

7. What is the resolution to the twin paradox?

8. Suppose the Michaelson-Morley experiment discovered aether. If the aether wind moved at exactly the speed of light and you fired a laser into the aether wind what would light's speed be? (Hint: this is before special relativity physics, think of the airplane problem).

9. You are describing the motion of a car. When will it become important to include special relativistic effects?

10. Why does the Foucault pendulum appear to rotate throughout the day?

11. We observe many muons on Earth, yet the muon's half-life suggests those created in the upper atmosphere should not make it to sea level. How is this possible?

12. According to special relativity, if you continue to push a ball by applying a constant force at some point you can hardly increase the velocity, yet you continue to do work on the ball. Where does this extra energy go?

13. A consequence of the strong equivalence is that light bends in a gravitational field. What startling suggestion did this lead Einstein to make about our spacetime geometry?

14. While sitting in this room taking this quiz, do you think your head or feet have aged quicker? Or neither?

15. Suppose you take a long voyage to a distant star and return home. You are paid at an hourly rate. Will you be paid more going by the Earth's clock or the ship's clock?

16. Recall that moving clocks run slow (relative to that same clock at rest). Suppose you could build a clock which ALWAYS ticked at the same rate as it does at rest, even if the special clock is in motion. How might you use this special clock to detect a universal rest frame? Such a clock is not allowed in physics – there are no preferred observers.

Problems – Required. Each worth 2 points

1. In Back to the Future 4 (the unreleased sequel) Marty goes 500 seconds into Earth's future in what seems to be 300 seconds to him by moving at $v = 140km/hour$. According to special relativity what would the speed of light need to be in the Back to the Future universe for this to happen? You can leave your answer expressed as some number times v.

Problems – Optional. Each worth 3 points.

1. Suppose Nolan Ryan could throw a fastball at $v = (4/5)c$. If a baseball's rest mass is $1kg$, what is the ball's mass while its in motion? What is its relativistic kinetic energy? How does this compare to the usual $\frac{1}{2}m_0v^2$ expression for the kinetic energy (greater, less equal)? For this problem you might need the formula $E = \gamma m_0c^2 = m_0c^2$+(relativistic kinetic energy).

2. Draw a spacetime diagram of the twin paradox problem. For this problem start by drawing a spacetime diagram where the twin on Earth is always located at $x = 0$ (but traveling forwards in time), and another twin travels to the right (positive x values), turns around and comes home. For the traveling twin's worldline what condition must you check for the worldline to be physically meaningful (Hint: no faster than light motion)? Can you draw the traveling twin's future on the spacetime diagram once they turn around to come back toward Earth, thus showing the return to Earth is possible?

1. In $d \geq 3$ spatial dimensions Newton's gravitational law becomes $F = G^{(d)} \frac{mM}{r^{d-1}}$ where $G^{(d)}$ is a constant. This suggests gravity's weakness (compared to the other forces such as electromagnetism) might be due to the fact that we live in a higher dimensional world. (i) Using dimensional analysis find a formula for the d dimensional plank length for arbitrary d dimensions. (ii) suppose $d-3$ of these dimensions are compactified, that is they are wrapped up into a "circles" of length L, using dimensional analysis show how L can be related to some combination of G^3 and G^d. (iii) $L^{(d-3)}$ is the volume of the compactified dimensions. Using previously derived formulas, relate $L^{(d-3)}$ to some combination of the d-dimensional plank length and the 3-dimensional plank length. This relation enables us to explore the possibility that the world is actually d-dimensional with a fundamental Planck length that is much larger than 10^{-35} meters. Of course, the 3-dimensional Plank length is 10^{-35} meters. Particle accelerators have probed length's down to 10^{-20} meters with no signs of extra dimensions yet.