THEORY OF RELATIVITY – FINAL QUIZ
JULY 7, 2011

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. According to special relativity, what two speed measurements will observers always agree on?

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 some 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. Equivalence of inertial and gravitational mass was suggested long before Einstein. Einstein takes this a step further with the strong equivalence principle. What is strong equivalence principle?

14. 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?

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

16. 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?

17. (BONUS) Nobody calls Marty McFly this name?

Problems – Required. Each worth 2 points

1. In Back to the Future 4 (the unreleased sequeal) Marty goes 500 seconds into Earth's future in what seems to be 300 seconds to him by moving at $v = 140 km/hour$. 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.

2. Suppose Nolan Ryan's could throw a fastball at $4/5c$. 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)?

Problems – Optional. Each worth 3 points.

1. (Relativistic Doppler shift) The relativistic energy E/c and momentum p form a 4-vector which transforms just like the coordinates t, x, etc – that is by a Lorentz transformation after identifying $\frac{E}{c}$ with t and p_x with x. Furthermore we have the usual expression

$$p_x^2 + p_y^2 + p_z^2 + m_0^2c^2 = (E/c)^2 \tag{1}$$

Which you've seen before, but now in terms of the momentum's vector components. Suppose a candle is emitting photons in the x direction with an energy E and momentum p_x in it's rest frame (recall $E = p_xc$ for light). Now suppose the candle is moving with a velocity v along the x-axis. What energy will be observed by someone located on the x axis? Using the quantum mechanics relationship $E = hf$ relate the frequency observed to the frequency in the candle's rest frame.

2. A sailboat is manufactured so that the mast leans at an angle θ' with respect to the deck. An observer standing on a dock sees the boat go by at a speed $v = .9c$. What angle does this observer say the mast makes?