Name ____________________ Date ________________ Class Sec. ____

Homework – Einstein's Relativity

Instructions: Use the attached reading on the next page to answer the questions below. Please answer in complete sentences. Make sure to explain your answer for full credit.

1. According to the passage, what effect happens when an object approaches the speed of light? Explain.

2. If a ball is thrown at 40 mph inside a train moving at 70 mph in the same direction, what is the ball's speed relative to a person standing near and still outside the train? What is the ball's speed to a person inside the train? Explain.

3. What is a reference frame, and how does it relate to motion? Explain.

4. How does the content of the reading contradict the A-theories of time? Explain.

READING IS ON THE NEXT PAGE

Einstein's Special Relativity by John Zavisa

Frames of Reference

Einstein's special theory of relativity is based on the idea of **reference frames**. A reference frame is simply "where a person (or other observer) happens to be standing". You, at this moment, are probably sitting at your computer. That is your current reference frame. You feel like you are stationary, even though you know the earth is revolving on its axis and orbiting around the sun. Here is an important fact about reference frames: **There is no such thing as an absolute frame of reference in our universe**. By saying *absolute*, what is meant is that there is no place in the universe that is completely stationary. This statement says that since everything is moving, all motion is relative. Think about it - the earth itself is moving, so even though you are standing still, you are in motion. You are always moving through both space and time. Because there is no place or object in the universe that is stationary, there is no single place or object on which to base all other motion. Therefore, if John runs toward Hunter, it could be correctly viewed two ways. From Hunter's perspective, John is moving towards Hunter. From John's perspective, Hunter is moving towards John. Both John and Hunter can observe the action from their respective frames of reference. All motion is relative to [compared with] your frame of reference. Another example: If you throw a ball, if the ball could see it would view itself as being at rest relative to you [think of how this is like being on Earth and the planets *looking* as though they rotate around us]. The ball can view you as moving away from it, even though you view the ball as moving away from you. Keep in mind that even though you are not moving with respect to the earth's surface, you are moving with the earth.

The First Postulate of Special Relativity

The first postulate of the theory of special relativity is not too hard to swallow: **The laws of physics hold true for all frames of reference**. This is the simplest of all relativistic concepts to grasp. The physical laws help us understand how and why our environment reacts the way it does. They also allow us to predict events and their outcomes. Consider a yardstick ruler and a cement block. If you measure the length on the block, you will get the same result regardless of whether you are standing on the ground or riding a bus. Next, measure the time it takes a pendulum to make 10 full swings from a starting height of 12 inches above its resting point. Again, you will get the same results whether you are standing on the ground or riding a bus. Note that we are assuming that the bus is not accelerating but traveling along at a constant velocity on a smooth road. Now if we take the same examples as above, but this time measure the block and time the pendulum swings as they ride past us on the bus, we will get different results than our previous results. The difference in the results of our experiments occurs because the laws of physics remain the same for all frames of reference. The discussion of the Second Postulate will explain this in more detail. It is important to note that just because the laws of physics are constant, it does not mean that we will get the same experimental results in differing frames. That depends on the nature of the experiment. For example, if we crash two cars into each other, we will find that the energy was conserved for the collision regardless of whether we were in one of the cars or standing on the sidewalk. Conservation of energy is a physical law and therefore, must be the same in all reference frames.

The Second Postulate of the Special Theory of Relativity

The second postulate of the special theory of relativity is quite interesting and unexpected because of what it says about frames of reference. The postulate is: **The speed of light is measured as constant in all frames of reference**. This can really be described as the first postulate in different clothes. If the laws of physics apply equally to all frames of reference, then light (electromagnetic radiation) must travel at the same speed regardless of the frame. This is required for the laws of electrodynamics to apply equally for all frames.

This postulate is very odd if you think about it for a moment. Here is one fact you can derive from the postulate: Regardless of whether you are flying in an airplane or sitting on the couch, the speed of light would measure the same to you in both situations. The reason that is unexpected is because most physical objects that we deal with in the world add their speeds together. Consider a convertible approaching you at a speed of 50 miles/hour. The passenger pulls out a slingshot and shoots a rock 20 miles/hour at you. If you measured the speed of the rock, you would expect it to be traveling at 70 miles/hour (the speed of the car plus the speed of the rock from the slingshot). That is, in fact, what happens. If the driver measured the speed of the rock, he would only measure 20 miles/hour, since he is already moving at 50 miles/hour with the car. Now if that same car is approaching you at 50 miles/hour and the driver turns on the headlights, something different happens?

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Since the speed of light is known to be 669,600,000 miles/hour, common sense tells us that the car's speed plus the headlight beam speed gives a total of 669,600,050 miles/hour (50 miles/hour + 669,600,000 miles/hour). The actual speed would measure 669,600,000 miles/hour, exactly the speed of light. To understand why this happens, we must look at our notion of speed.

Speed is the distance traveled in each amount of time. For example, if you travel 60 miles in one hour, your speed is 60 miles per hour. We can easily change our speed by accelerating and decelerating. For the speed of light to be constant, even if the light is "launched" from a moving object, only two things can be happening. Either something about our notion of distance and/or something about our notion of time must be skewed. As it turns out, both are skewed. **Remember, speed is distance divided by time.**

The Effect of Motion on Time
I mentioned that time also changes with different frames of reference (motion). This is known as "time dilation". Time slows with motion, but it only becomes apparent at speeds close to the speed of light. If an object's speed reaches that of light, time slows to a stop. Again, only an observer that is **not in motion with the time** that is being measured would notice. Like the tape measure in length contraction, a clock in motion would also be affected so it would never be able to detect that time was slowing down (remember the pendulum). Since our everyday motion does not approach anything remotely close to the speed of light, the dilation is completely unnoticed by us, but it is there.

In the past, to attempt to prove this theory of time dilation, two very accurate atomic clocks were synchronized, and one was taken on a high-speed trip on an airplane. When the plane returned, the clock that took the plane ride was slower by exactly the amount Einstein's equations predicted. Thus, a moving clock runs more slowly when viewed by a frame of reference that is not in motion with it. Keep in mind that when the clock returned, it had recorded less time than the ground clock. Once re-united with the ground clock, the slow clock will again record time at the same rate as the ground clock (obviously, it will remain behind by the amount of time it slowed on the trip unless re-synchronized). It is only when the clock is in motion with respect to the other clock that the time dilation occurs.

Simultaneous Events
Simultaneous means two or more things happening at the same time. According to Relativity, there is no such thing as simultaneity between two events when viewed in different frames of reference. If you understand what we have talked about so far, this concept will be a breeze. First let's clarify what this concept is stating. If Meagan sees two events happen at the same time for her frame of reference, Garret, who is moving with respect to Meagan, will not see the events occur at the same time. Let's use another example. Imagine that Meagan is standing outside and notices that there are two identical cannons 100 yards apart and facing each other. All the sudden, both cannons fire at the same time and the cannonballs smash into each other at exactly half their distance, 50 yards. This is no surprise since the cannons are identical and they fire cannonballs at the same speed. Now, suppose that Garret was riding his skateboard super-fast towards one of the cannons, and he was directly in the line of fire for both. Also suppose he was exactly half-way between the two cannons when they fired. What would happen? The cannonball that Garret was moving towards would hit him first. It had less distance to travel since he was moving towards it.

Now, let's replace the cannons with light bulbs that turn on at the same time in Meagan's frame of reference. If Garret rides his skateboard in the same fashion as he did with the cannonballs, when he reaches the halfway mark, he sees the light bulb he is moving towards turn on first and then he sees the light bulb he is moving away from turn on last.

Like the cannon ball on the right hitting first, he would witness the bulb on the right turn on first even if both were turned on at the same time. Since he is moving toward the bulb on the right, its light has a shorter distance to travel to reach him. **Garret would argue with Meagan that the bulbs did not turn on at the same time, but in Meagan's perspective they did.** Hopefully, you can see how different frames of reference will not allow events to be observed as simultaneous.