Core Ideas of Unit 3 – Same Laws for All

The Principle of Relativity states as a postulate that the laws of physics are the same in all free-float reference frames. So far, there is not one iota of experimental evidence to suggest that this is not the case. Consequently, there is no experiment that can be done to establish that a particular free-float frame is stationary while all other free-float frames are moving with respect to that particular frame. Each free-float observer is allowed to declare that her frame is stationary while all others moving with respect to her. But that same choice is available for observers in any other free-float frame and there is no experimental way to determine which, if any, of the different reference frames is really at rest!

A consequence of the Principle of Relativity is that all observers in free-float reference frames must measure the same value for the speed of light regardless of the velocity of the device emitting the light. Stating that all free-float observers measure the same value for the speed of light independent of the source of the light is easy and masks the counter intuitive nature of the statement. Spend a little time thinking about what this means. (Michelson and Morley, in their famous experiment with an interferometer, were attempting to measure the small difference in the speed of light caused by the motion of Earth about the Sun. From their perspective, their failure was a tremendous source of frustration. But in fact they were trying to measure a difference that did not exist! <u>See problem 3-12 for a more detailed discussion of this famous experiment</u>.)

The constancy of the speed of light leads directly to the strange but necessary conclusion that simultaneity is relative. That is two events that happen simultaneously in reference frame A do not happen simultaneously in any reference moving with respect to reference frame A. The relativity of simultaneity also leads to the Lorentz contraction of moving rods and many of the other "paradoxes" of special relativity.

The invariance of the interval is revisited. Be sure to understand that this invariance depends on the fact that free-float observers moving with respect to one another necessarily measure different space and time separations between spacetime events.

Assignment for Unit 3

1) Keeping the core ideas in mind, carefully read through **Chapter 3: Same Laws for All** in its entirety.

2) Now start re-reading the chapter with pencil and paper in hand.
3) What did you learn by reading Box 3.2?
4) Before looking at the answers to Sample Problem 3.1, spend a little time identifying the quantities or laws that stay the same and those that change when viewed from two free-float frames moving with respect to one another.
5) Carefully study Einstein's trains in figure 3.1. Now your job is to quantify the description of the events depicted in that figure. Assume the Earth-bound observer measures the distances between the two lightning flashes to be D meters and the velocity of the train to be v meters/second. In terms of D, v, and c calculate the following times:
    a. The time the Earth-bound says it takes the flash from the front of the train to reach the train-bound observer. Call that time t_1.
    b. Then calculates the time it takes that flash to reach the Earth-bound observer. Call that time t_2.
    c. Next calculate the time it takes the flash from the rear of the train to reach the train-bound observer.
    d. Call that time t_3.
    e. Lastly, calculate the time it takes that flash to reach Earth-bound observer. Call that time t_4.

    Are your answers consistent with the narrative associated with figure 3.1?

6) Be able to qualitatively explain why the measured length of a rod that is at rest in a free-float frame is larger than the length measured by other free-float observers that are moving in a direction parallel to the rod. What is the definition of "proper length?"
7) Convince yourself that these effects of special relativity happen for events that are situated along the direction of motion. There are no "surprises" for events that are oriented perpendicular to the direction of motion.
8) Sections 3.7 and 3.8 quantitatively demonstrate the "invariance of the interval." What assumptions are necessary in order for the argument to work?
9) In Sample Problem 3.2, the experimental data is given with respect to the laboratory. Note that the question asks for the half life of the K^+ in its rest frame.
10) Be sure to spend some time thinking about the material in Box 3.3 and the six items in the chapter's summary. How fast would a rocket have to go to travel from the

Milky Way to the Andromeda galaxy, two million light-years, in one day of rocket time? Write the answer as a decimal fraction of light speed, 0.999….

11) Do practice exercises 3.1, 3.4, and 3.5.
12) Do problems 3.7, 3.10, 3.11, 3.12, 3.15, and 3.16.
13) When finished with the practice exercises and problems, bring them by my office. If everything looks okay, you will be given a quiz to test your mastery of the material in Unit 3.