

1. READING

Ellis and Williams, *Flat and Curved Space-times*

Chapter 2 This is a discussion of the operational definitions of measuring location and time using light.
 Chapter 3 many of the unusual effects of special relativity are worked out here using space-time diagrams. Sections 3.1 - 3.3 will be most relevant for classes on September 18 and 23, although we will skip pages 58-9 since it involves background we don't necessarily have. Looking ahead as best I can, sections 3.4 (time dilation redux), 3.5 (length contraction), and perhaps 3.6, (the whole kit and kaboodle) will be discussed on the 25th and 30th.

2. QUESTIONS: DUE WEDNESDAY, SEPTEMBER 24 BY 5 PM

- (1) Two, identical (excepting paint schemes), elastic balls collide. Before the collision, the pink ball on the right moves to the left at 10 ms^{-1} while the white ball on the left is stationary.
 - (a) Make a space-time diagram of the collision in the original frame.
 - (b) Make a space-time diagram of the collision in a frame moving at -5 ms^{-1} .
- (2) Ellis and Williams 1.5
- (3) As you recall from the Week 1 assignment - Alice is on her way to the dining car of a super-fast WorldStar train but pauses half-way down the car to talk with a friend. A little while later, lighting bolts strike the front and back of the train, leaving char marks on the ground. Alice observes the flashes of light from the lighting simultaneously. Bob is a dedicated trainspotter, in macintosh, standing on the ground watching the train pass. Suppose he also sees both flashes from the lighting strikes in the same instant.
 - (a) Sketch a space-time diagram of the history as seen from Bob's frame. Be sure to include the light from the lighting strikes and the worldlines of Bob, Alice, the train, and the char marks on the ground.
 - (b) Sketch a space-time diagram as seen from Alice's frame, including the same elements as in part (a).
- (4) Two volcanoes, Mt. Rainier and Mt. Hood, are 500 km apart in their rest frame. Suppose that each erupts in a burst of light. An observer in a lab halfway between the two volcanoes receives the light from the two blasts at the same time. The observer's assistant is at the base of Mt. Rainier. The above objects (mountains, observer, and assistant) are at rest with respect to each other. A spacecraft flying by at 80 % of the speed of light from Rainier to Hood is directly over Mt. Rainier when it erupts. According to an observer on the spacecraft does the eruption at Mt. Rainier occur before, at the same time, or after the eruption at Mt. Hood? To answer this use a space-time diagram. Assume the mountains and observers are all on a single line. You can also neglect any non-inertial effects due to being on the surface of the Earth.
- (5) Ellis and Williams 1.7
- (6) Ellis and Williams 1.8
- (7) Ellis and Williams 3.5
- (8) Ellis and Williams 3.10
- (9) The Hafele-Keating experiment.
 - (a) What is a typical passenger aircraft speed in m/s?

- (b) An experimental test of the “twin paradox” was done in October 1971 with two atomic clocks. J. Hafele and R. Keating took atomic clocks, one eastward, one westward, around the world twice using commercial airlines. When they returned they compared the their times with the clock at the US Navel Observatory. Compute the value of

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$$

by first using a calculator. (It is a tiny effect! Your calculator may not report many digits.)

- (c) Using the approximation (for $x < 1$)

$$(1 - x)^a \approx 1 - ax$$

with $a = -\frac{1}{2}$ to find the “leading order” correction, $-ax$. (If you are skeptical about this relation try it out for a few examples.)

- (d) Assume that one leg of the flight took 14 hours. On this leg of the trip, by how much did the traveling clock disagree with the clock that stayed “home”? Please state your results in seconds.

Interestingly, Hafele and Keating had to account for general relativistic effects as well. With these effects, they found agreement between their experiment and the theoretical predictions.