1 A Bike Ride

You are riding your bike along a long, straight road when Mark rides by you on his bike. You see that he is moving 10 m/s faster than you.

30 seconds after Mark passes you, you notice that a car 40 meters ahead of you honks.

(a) *Sensemaking: Compare Quantities* What fraction of the speed of light is a typical bike-riding speed? Based on this fraction, is it appropriate to use Galilean Relativity for this situation, or should you use Special Relativity?

(b) *Sensemaking: Represent the Physical Situation with a Diagram* Draw a spacetime diagram of the situation.

- Choose the origin to be when Mark passes you on your bike.
- Draw the worldlines of you and Mark.
- Label all the axes and the event where the car honks its horn.

(c) What are the spacetime coordinates of the honk in both (a) your reference frame and (b) Mark's reference frame? Indicate with dashed lines how you would read these coordinates off your spacetime diagram.

(d) *Sensemaking: Look for Invariant Quantities* Do you and Mark agree on the distance between Mark and the car honk?

(e) *Sensemaking: Look for Invariant Quantities* Do you and Mark agree on the time interval between when Mark passed you and when the car honks?

2 Satellite

(*Taylor 15.3*)

A low-flying earth satellite travels at about 8000 m/s.

(a) What is the factor γ for this speed? (Hint: You'll need to keep a lot of significant figures for this whole problem.)

(b) The ground-based clocks measures an hour of time. At that moment, how much does the satellite's clock differ from the ground-based clock?

(c) *Sensemaking: Compare Quantities* What is the percent difference between the clocks (as measured by the ground-based clock)? Comment on whether your answer seems reasonable for the problem situation.

3 Spock's Vacation

(Taylor 15.6)

When he returns from his Hertz rent-a-ship after one week's cruising in the galaxy, Spock is shocked to be billed for three weeks' rental! Assume that he traveled straight out and then straight back, always at the same speed.

(Note: This is similar to the famous "twin paradox" which we will explore in more detail later. It is fairly easy to get the right answer by judicious insertion of a factor of γ in the right place, but to understand it, you need to recognize that it involves 3 different inertial frames: the Earth-bound frame, Spock's outgoing frame, and Spock's incoming frame. Consider the two halves of the trip seperately. Notices that the situation for Spock and Hertz is not symmetric: Hertz stays in the earth-bound frame while Spock is in both the outgoing and incoming frame. This is what allows the result to be unsymmetrical.)

(a) *Sensemaking:* Draw a spacetime diagram of the situation and label the important events.

(b) How fast was Spock traveling relative to Earth?

(c) Find a general expression for β in terms of γ and plot it using plotting software.

  (a) *Sensemaking:* Does the *behavior of the function* match your conceptual expectation? Explain.

  (b) *Sensemaking:* Do the *special cases* of (i) no relative motion and (ii) relative speed of the speed of light match your expectations? Explain.

4 Derive Time Dilation with a Light Clock

Explain (with words and equations) the derivation of time dilation using a thought experiment with a light clock:

Relate the time interval of a tick of a light clock as measured by observers in two different frames. (This was done in class and is in Taylor 15.4).