Special Relativity—Homework 2

1. You see a muon traveling at a speed $\beta = 0.99$ and measure its lifetime to be 15.6 $\mu$s. If the same muon was at rest in your lab, what would be its lifetime?

2. Your friend carries a meter stick at a high speed past you. How fast must your friend move if you measure the length of her meter stick to be 30 cm?

3. Tom measures the time interval between two events to be 150.0 ns and the separation of the two events to be 80.0 ns.
   (a) Dick measures the separation of the same two events to be 120.0 ns. What does Dick measure for the time interval?
   (b) Harry observes the proper time interval between the two events. What is this proper time interval?
   (c) According to Harry, what is the speed of Tom?

4. Ben and Jerry are the two observers, and according to Ben, Jerry is moving to the right. Consider events
   - E1: Jerry tosses ball up into the air
   - E2: Ball reaches its maximum height
   - E3: Ball returns to Jerry’s hand and is caught.
   (a) Who is the proper observer of the time interval between E1 and E2, Ben, Jerry, or neither. Explain.
   (b) Who is the proper observer of the time interval between E1 and E3, Ben, Jerry, or neither. Explain.

5. An elementary particle is moving through my lab. I measure it to have a speed of $0.960c$ ($\beta = 0.960$) and a lifetime of 150 ns (nanoseconds).
   (a) You move at the same velocity as the particle. For you, what is the lifetime of the particle?
   (b) According to me, how far does the particle travel during its lifetime?
   (c) According you, how far does the particle travel during its lifetime? (Read the question carefully!)

6. Al rides in train Alpha, and Beth rides in train Beta. According to Al’s measurements, Train Beta moves to the right at $\beta = 0.800$ and takes 15.0 ns to pass his location. According to Beth, Alpha passes her in a time of 20.0 ns.
   (a) According to Al, what is the length of Beta? Is this a proper or improper length?
(b) According to Beth, what is the length of Alpha? Is this a proper or improper length?

(c) According to Al, what is the length of Alpha? Is this a proper or improper length?

(d) According to Beth, what is the length of Beta? Is this a proper or improper length?

(e) According to Al’s measurements, which train is longer?

(f) According to Beth’s measurements, which train is longer?

7. Annabelle sees Boris moving in his spaceship to the left. Annabelle measures the time needed for Boris’s ship to pass her location as $\Delta t = 15$ ns, and Boris tells her that his ship has length $L = 20$ ns.

(a) Are this time interval and this length proper or improper?

(b) Why can’t we just determine the speed by dividing the given distance by the given time interval?

(c) Find the velocity of Boris as measured by Annabelle.

8. Brad is located at the left end of a box that he measures to be 20 m long. At the far end of the box is a mirror. Brad carries a laser pointer that he can briefly flash.

Carrie sees Brad and the box move to the right at $\beta = 0.60$. Consider the events (E1) Brad sends laser pulse, (E2) the pulse reflects from mirror, and (E3) the pulse returns to Brad.

(a) How long is the box as measured by Carrie?

(b) On gridded paper, draw a space-time diagram for the sequence of events as seen by Brad. Include labeled world lines for Brad, Carrie, the mirror, and the light as it travels to the mirror and returns. Show the events as labeled dots.

(c) On gridded paper, draw a space-time diagram for the sequence of events as seen by Carrie. Include labeled world lines for Brad, Carrie, the mirror, and the light as it travels to the mirror and returns. Show the events as labeled dots.

(d) Suppose that E1 occurs at $t = 0$ m, $x = 0$ m. According to Brad, what are the coordinates of E2 and of E3?

(e) According to Carrie, what are the coordinates of E2 and of E3?

(f) Consider the interval E1 to E3? Do Brad, Carrie, neither of them, or both of them measure the proper time interval between these two events?