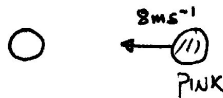


1. READING

Ellis and Williams, *Flat and Curved Space-times* Chapter 1 - This reading introduces space-time diagrams and their use. Our treatment of reference frames is briefly discussed in various places in the first two chapters.

2. QUESTIONS: DUE WEDNESDAY, SEPTEMBER 10 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 8 ms^{-1} while the white ball on the left is stationary, as shown.



In the original reference frame, what happens after the collision?

- The pink ball moves at 8 ms^{-1} while the white ball is stationary.
- Both balls move at -4 ms^{-1} .
- The balls move away from each other at 8 ms^{-1} .
- The pink ball is at rest and the white ball velocity is -8 ms^{-1} .
- The balls move away from each other at 4 ms^{-1} .

Please explain your reasoning for your answer.

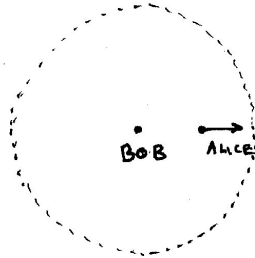
- (2) Two identical, sticky objects collide. What happens if the one on the left, moving at 2 ms^{-1} , collides with the stationary one on the right?
- Both move at 2 ms^{-1} to the right
 - Both are at rest
 - Both move at 1 ms^{-1} to the right
 - They stop because they stick together
 - There is not enough information to answer this question.
- Please explain your reasoning for your answer.

- (3) A “small” ball collides with a “big” ball. What happens if the big ball, on the right, moves to the left at 10 ms^{-1} and collides with the stationary small ball? In this frame of reference, the final velocities are
- small: -10 ms^{-1} , big: 0 ms^{-1}
 - small: -15 ms^{-1} , big: -5 ms^{-1}
 - small: -10 ms^{-1} , big: -10 ms^{-1}
 - small: -20 ms^{-1} , big: -10 ms^{-1}
 - small: -20 ms^{-1} , big: 0 ms^{-1}

Please explain your reasoning for your answer.

- (4) A well-equipped inertial observer, you have accurate meter sticks, synchronized clocks, and assistants. A beeper a distance d away beeps. Describe the procedures to find the time when the beep was emitted in your reference frame

- (a) using the speed of sound in air and
 - (b) without using the speed of sound in air.
- (5) You sip coffee (or other favorite hot beverage) then put the cup down. In the seat on your right a woman types hastily at the keyboard. On your left a boy about 14 years old listens to bagpipes, which you can easily hear given the volume, and holds the iPod languidly in one hand. From this description can you tell whether you are flying at 540 mph, taxiing, sitting on the runway, or still in Terminal C at Newark airport?
- (6) A horn is placed between an observer and a distant beeper. The observer hears the sounds from both horn and beeper in the same instant. Sketch the observer, horn, and beeper. In the observer's frame, which of the horn or beeper goes off first, or did they go off at the same instant?
- (7) If you answered the last question with "horn" or "beeper", how can you, being a well-equipped observer, determine the time interval between the emission of the sounds?
- (8) Alice and Bob move past each other at nearly the speed of light. At the instant they high five in passing, a spark passes between them emitting a flash of light. Here's what it looks like in Bob's frame a short time later:



The dotted circle shows the light traveling outwards from the source, the spark.

- (a) Draw the light front and Alice a short time later
 - (b) Now sketch these same pictures in Alice's frame.
- (9) A super-fast WorldStar train moves uniformly. Alice is on her way to the dining car 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. Bob is a dedicated trainspotter, in macintosh, standing on the ground watching the train pass. He sees both flashes from the lighting strikes in the same instant.
- (a) Sketch the situation from the ground, just before the light flashes reach Bob. Be sure to include the light fronts, Bob, the char marks on the ground, and the train.
 - (b) Sketch the view from the ground, shortly after the lighting strikes. (This will be *before* your previous picture). Be sure to include the light fronts, Bob, the char marks on the ground, Alice, and the train.
 - (c) What does Alice, standing in the center of the car, see? Write a description of the events from her point of view.
 - (d) Switch to Alice's frame, describe in pictures and/or words the order of the events: lighting strikes and observations of the flashes of light by Alice and Bob.
- (10) 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. According to the assistant does the eruption at Mt. Rainier occur before, at

the same time, or after the eruption at Mt. Hood? Please explain your answer with pictures and/or words. 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.

- (11) In Bob's reference frame Alice moves uniformly to the right at v . A firecracker goes off half-way between two sign posts as shown.



Alice's assistants note down the time when the sign posts are illuminated. When they compare notes, they determine that the sign posts were illuminated simultaneously. Show what Bob observes by sketching the posts and location of the exploding firecracker in his frame at a time t after the firecracker has gone off. In Bob's frame are the signposts illuminated simultaneously?