Spacetime & the Quantum World: Guide 1

Fall 2025 v1.0

1. Reading: For this assignment

Mermin, *It's About Time* Chapters 1-3

2. Reading: Looking ahead

Ellis and Williams, *Flat and Curved Space-times* Chapter 2 - the operational definition of measurement of time and distance. Chapter 3, section 3.1.

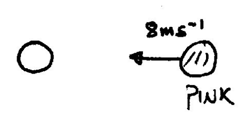
Mermin, *It's About Time* Chapter 4 A careful description of relativistic velocity addition.

(optional) Ellis and Williams, *Flat and Curved Space-times* Chapter 1 (not on eReserves due to copyright law) introduces space-time diagrams and their use. There is a copy of the book in the library. Our treatment of reference frames is briefly discussed in various places in the first two chapters.

(optional) On the Light Clock - Styer, *Relativity for the Questioning Mind* pages 24-32. (Now available from Johns Hopkins University Press)

3. Questions: Due Thursday, September 11 by 11 PM on Gradescope (code ZY635K).

(1) Consider the elastic collision of a pink ball (on the right) that moves to the left at 8 ms^{-1}. The white ball on the left is stationary, as shown.



(a) Which frame should you choose to convert this to a known situation?
(b) In the original reference frame, what happens after the collision?
(c) Which invariant principle are you using to answer this question by switching reference frames?

(2) Two elastic spheres collide. Before the collision the sphere on the left moves to the left at 40 m/s while the sphere on the right, which has the same mass, moves to the left at 60 m/s.
(a) Sketch the initial configuration in the original frame.
(b) What frame should you choose to convert this to a known situation used in class?
(c) What is the final outcome of the collision in the original frame?

(3) Two identical, sticky hockey pucks collide. What happens if the one on the left, moving at 2 ms^{-1}, collides with the stationary one on the right? Please explain your reasoning using the "switching between reference frames" method and drawing diagrams.

(4) A "small" ball collides with a "big" ball. What happens if the big ball, on the right, moves to the left at 7.8 ms^{-1} and collides with the stationary small ball? In this frame of reference, what are the final velocities? Please explain your reasoning using the "switching between reference frames" method.

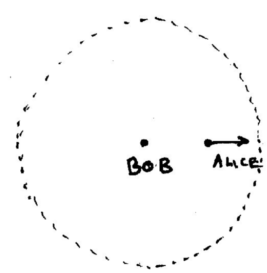
(5) A well equipped inertial observer, you have accurate meter sticks, synchronized clocks, and assistants. A beeper a distance d away will emit a "beep" sound. You know that this will happen and wish to establish when this beep occurs. Describe the procedures to find the time when the beep was emitted in your reference frame two ways:
(a) Using the speed of sound in air and no assistants.
(b) Using neither the speed of sound in air nor light but with assistants.

(6) *You are on a flight. Sipping coffee (or other favorite hot beverage) you notice that in the seat to 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 iPhone languidly in one hand.* From these observations could you tell whether you are flying at constant 540 mph, taxiing, sitting on the runway, or still in waiting outside the terminal? Explain your answer. (Please ignore any FAA rules regarding the use of computers and music players.)

(7) 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? Using a spacetime diagram and words, explain your answer.

(8) In class on September 2 you measured the speed of light. Briefly explain the experiment - using diagram(s) is fine. State the distance the pulse of light traveled and the time it took. Compute the speed of light using your numbers.

(9) Alice and Bob move past each other at nearly the speed of light. At the instant they pass, a spark passes between them emitting a flash of light. Here is the situation in Bob's frame a short time later:



The dotted circle shows the light front traveling outwards from the source, the spark.
(a) Draw the light front and Alice a short time after the above picture.
(b) Now - in Alice's frame - sketch the two situations again a short time after Alice and Bob pass and again a short time later, i. e. draw the same sketches in Alice's frame.

(10) Two volcanoes, Mt. Boom and Mt. Doom, 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

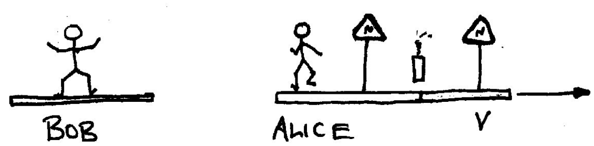
of Mt. Boom. The above objects (mountains, observer, and assistant) are at rest with respect to each other.

(a) According to the assistant does the eruption at Mt. Boom occur before, at the same time, or after the eruption at Mt. Doom? Please explain your answer.

(b) Draw a series of diagrams of the light fronts or a spacetime diagram of the history.

Assume the mountains and observers are all on a single line.

(11) Bob observes Alice, and two signs and a firecracker, moving uniformly to the right at v. A Super-Duper firecracker, half-way between two sign posts, explodes in a flash of light. Nothing else remains of the firecracker. Before the firecracker explodes the situation in Bob's frame is this:



Alice's assistants note down the time when the sign posts are illuminated. When they compare notes, they determine that the spin 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, i.e. are the events of the light reaching the sign posts simultaneous? One way to answer this is to draw a sequence of situations as above, showing what happens to the light fronts.