Spacetime and the Quantum World: Guide 3
Fall 2025 v1.0

1. Reading: For this assignment

Mermin, *It's About Time* Chapters 7, 8, and 10. Mermin covers "K" in Chapter 7. The interval is in Chapter 8. He has a (slightly idiosyncratic) introduction to spacetime diagrams and the interval in Chapter 10. Depending on time and interest we may return to "$E = mc^2$" in Chapter 11.

(Optional but helpful!) **Ellis and Williams**, *Flat and Curved Space-times*
Section 3.6, (the whole kit and kaboodle) will (probably) be discussed the week of September 23. Some of Chapter 3 is available on Blackboard. The book should also be on reserve in the Library.

For a taste of curved geometry you can see Ellis and Williams sections 5.1-5.3.

2. Reading: Looking ahead

Styer, *The Strange World on Quantum Mechanics* Chapters 1, 2, and 3. We will start on Styer's material on October 14, just before break. For this class read Chapters 1 and 2.

3. Questions: Soft due date Tuesday, October 15 by 11 PM. Deadline Tuesday, October 21 by 11 PM. So you can plan, the next guide will be due October 30.

Please submit your solutions using Gradescope (code ZY635K). (You can also get to this through Blackboard: 135 - Tools - Gradescope).

(1) We return to Marcus, Ovid, and Cattallus: On teh last guide on a rocket, Marcus moves away from Ovid to the left at $-\frac{3}{4}c$, and Cattallus, also on a shiny new rocket, moves away from Ovid to the right at $\frac{3}{4}c$. Last time we drew the spacetime diagram in Ovid's frame.
   (a) What relative velocity does Cattallus determine for Marcus?
   (b) What is the rate of increase of the separation between Marcus and Cattallus in Ovid's frame? You can use your previous (guide 2) space-time diagram.
   (c) Draw a space-time diagram for Cattallus's frame.
   (d) Explain how this is all consistent within special relativity, particularly the maximum bound on a speed (appropriately defined!) of c.

(2) Click on the "example 2" spectrum on the course webpage. What is the redshift z for this galaxy?

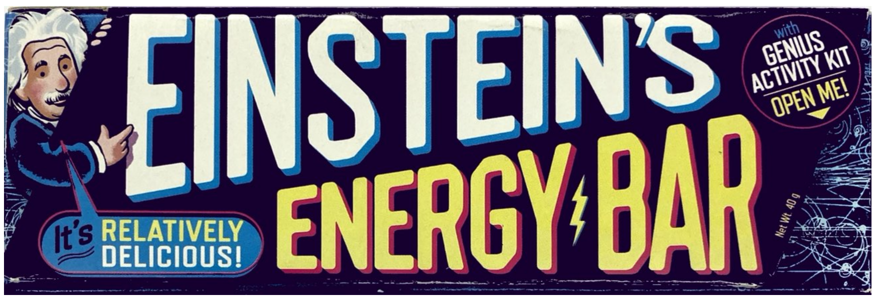
(3) In your own words and diagrams explain why two events simultaneous in one frame will occur at different times in any other frame. In Special Relativity, what is this ultimately based on?

(4) If
$$v = +\frac{15}{17}c$$
then what are K and γ equal to? Hint: It is easiest to work this out in terms of fractions

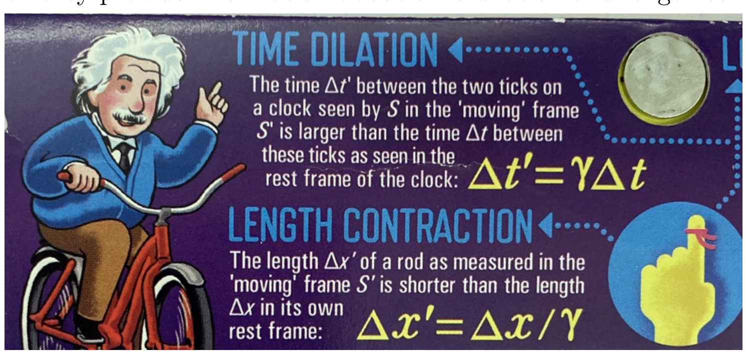
(5) A friend buys a *really* fast car. After trying out the car on a stretch of straight and empty road your friend is stopped for running a red light ($\lambda \approx 650$ nm) in a 45 mph zone. Knowing something of relativity, your friend decides to contest the ticket in court where your friend simply states that the light appeared to be green ($\lambda \approx 550$ nm). The judge agrees!

(a) Find the factor K for the shift from the red to green light. The driver approached the light.
(b) How fast was your friend going?
(c) Why does the judge agree that your friend saw a green light?
(d) Unfortunately, the judge changes the charge to speeding. If the fine is 0.01 dollar for every mile per hour over 45 mph, what is the fine, approximately? You can use the conversion 2.2 mph $= 1.0$ ms^{-1}.

(6) The "Unemployed Philosophers Guild" produces a (as it says) 'relatively delicious' chocolate bar packaged in an amusing box. Here's the top



Inside this box they provide information about time dilation and length contraction:



Sadly one of these effects is described incorrectly. Which one? And what relatively small change in wording would correct the statement?

(7) In the 'ladder in barn' situation discussed in class, let the speed of the runner be 0.866c in the barn's frame. Please assume that the proper lengths of both the ladder and the barn are 5 m.

(a) Compute γ.
(b) What is the length of the ladder in the barn's frame?
(c) What is the length of the barn in the ladder's frame?
(d) The runner with the ladder arranges things (for instance by attaching rockets to the ladder) so that the ladder comes to a stop when the front of the ladder reaches the back of the barn. This is done in the proper frame of the runner. Does the ladder fit in the barn at any time?

(e) Describe the sequence of events in the barn's frame.

(8) A steel cable connects two trains at rest on the same track. The cable will snap if it is stretched by as much as 1%. The trains accelerate in such a way as their velocities, as measured in the ground frame, are always equal. Eventually the cable snaps. Explain why this happens in the two frames, ground and train. How fast are the trains moving when the cable snaps?

(9) Suppose two ("Ovid" and "Brian") equal-length whales pass each other at 3/5 c. Draw a space-time diagram of this history in Ovid's frame. Using this one diagram show that Brian's length is contracted in Ovid's frame AND Ovid's length is contracted in Brian's frame. [Hint: Draw a surface of simultaneity for Brian to see the second part.]

(10) At the end of the science fiction novel *Death's End* by Cixin Liu two travelers make their way from Pluto to a star system 287 light years away in the first near lightspeed ship to be constructed by humanity. [1] They arrive after 52 hours on board the spacecraft.

(a) Find the γ factor of the spacecraft neglecting the time elapsed for acceleration at the beginning and end of the trip.

(b) At these speed we have to be a bit more careful with finding the speed - the straightforward calculation gives "c" which is not quite correct. Instead compute the relative difference of the ship's speed and the speed of light:

$$\frac{c-v}{c}$$

The will be a very small (but non-vanishing) number.

[1] The ship evades restrictions on light-like travel by curving the geometry around it. In the GR class I can say a but more about these "warp drive" solutions to Einstein's equations.