1. Consider the guy in the middle of the boxcar that is moving at a speed $v$ relative to a station and a guy at the station, call them Joe, on the car, and Harry. When the two guys pass each other, a light flash is generated that travels to the front and back of the car. We agree that Joe says that the two light pulses arrive at the ends of the car simultaneously and the Harry says that the light hits the back of the car and then the front. Draw this on a space time diagram first from Joe’s point of view including Harry and the ends of the boxcar. Now do Harry’s point of view including Joe and the boxcar. Assign an arbitrary length to the boxcar and find the slope of Joe’s line of simultaneity in Harry’s diagram. Using this result, now show the lines of simultaneity for Harry on Joe’s diagram and explain the sequence of the light pulses from Harry’s perspective.

2. A cornerstone of the theory of special relativity is the constancy of the speed of light in all reference frames. Also we require Galilean invariance and that empty space is homogeneous and isotropic. Consider two mirrors positioned opposite from each other and a photon reflecting to and fro between the two mirrors. An observer at rest with regard to these mirrors sees the photon bouncing up and down. This setup can be used as a clock; you count the number of times the photon performs one cycle of its motion, i.e. leaves mirror A, hits mirror B, reflects back to mirror A, hits mirror A. Let’s us this as our definition of time. Now another Galilean related observer makes an identical clock. To do so he aligns his mirrors with yours. Note that this is only possible if the shortest line between the mirrors is transverse to the direction of relative motion. To that observer his clock runs the same as yours but you see this ‘clock’ pass you with constant velocity. For you, it seems as though the photon is moving along a zigzag path (this is required so that it return to the same place on the mirror that is moving at constant velocity). Taking the separation between the mirrors to be $L$, calculate the length of the path the photon travels to complete one cycle in the two cases. In the second case, you will need to make use of the fact that the photon velocity is the same constant $c$ in every frame to calculate this time. Your answer will also depend on the velocity $v$ of the mirrors relative to you. Note that the ratio of the times is independent of $L$ and thus compare the time interval on the moving clock with your clock. Now our moving friend turns his clock sideways, along the direction of relative motion. He of course concludes that his clock runs the same, his space is isotropic. Requiring that the slowdown in the running of relatively moving clocks is independent of their orientation, show that for this new arrangement that you no longer think that the mirrors are a length $L$ apart and compute the ratio of the distances that you say is between the mirrors.

3. Harry and Sally have been together for a while, and Sally needs her space; so she hops on a coasting rocket and heads out of the solar system at $\frac{3}{5}c$ for two days (according to her). She stops in the Oort cloud (a collection of dirty snowballs beyond the orbit of Pluto from which it is believed the comets come) and spends a day thinking. Then she decides she really does love the big lug after all, and she heads home at the same speed at which she left. Over all, according to her, the trip took five days.
(a) How long was she gone according to Harry? How far away from the earth did she travel? How far from the earth does Sally think she traveled? Explain the discrepancy.

(b) On a sheet of graph paper draw a space-time diagram (to proper scale) showing everything that happened from Harry’s point of view.

(c) Every 6 hours lovelorn Harry sends Sally a message at the speed of light; draw these messages (preferably in a different color) on your space-time diagram. Using the diagram, determine how often Sally receives Harry’s missives while she is flying away, while she is at rest in the Oort cloud, and while she is coming back. Compare your graphical results with the formula for the Doppler effect.

(d) What if Sally had sent out the lovelorn signs instead of Harry?

(e) When Sally reaches the Oort cloud, how much time does she believe has passed for Harry? Verify this by drawing a line of simultaneity for Sally just as she reaches the cloud (before she slows down). Now draw another line of simultaneity for Sally at the same place just after she slows down. How much time has passed on earth for Harry that Sally does not know about?

(f) When Sally sets out for home, she knows it will take two days to return; how much time should pass for Harry while she is coming back? Verify this by drawing a line of simultaneity for Sally just after she sets out for home. Also draw a line of simultaneity for Sally just before she sets off. How much time has passed on earth for Harry that Sally does not know about? (I certainly hope you see the resemblance between this part and the last part.)

(g) Add up the times that Sally says passed on earth while she was heading away, staying in the Oort cloud, and heading home, and compare this to the time Harry says passed. Where did the difference go?

4. Harry is moving toward Sally at \( \frac{4}{5}c \) from the left to the right. Sally notes that, simultaneously with the arrival of Harry, there are three explosions at positions 2 ly, 3 ly, 4 ly to the right. When and where does Harry say that these explosions take place? From when on is each of the explosions unambiguously in Sally’s past? From when on is each of these explosions unambiguously in Harry’s past according to Sally? According to Harry?

5. Do Problem #1.5 in “Traveler’s Guide”.

6. Do Problem #2.8 in “Traveler’s Guide”.

7. Do problem #2.12 in “Traveler’s Guide”.

8. Do problem #3.7 in “Traveler’s Guide”.


10. Do problem #4.9 in “Traveler’s Guide”.

Home experiment #7: There is no home experiment this week. There is enough stuff to do above.