Intermediate Dynamics: Homework 7

Due: 9 October 2013

1 Supernovae

Two stars α and β are at rest with respect to each other and, in their rest frame are separated by $40c\cdot$ yr. A space station, at rest relative to the stars, is midway between them. According to the space station observer, a flash of light arrive from each star, indicating a supernova, at $t = 0\,\text{yr}$. At exactly this moment a rocket ship passes the space station, with its clock reading $0\,\text{yr}$ and is traveling at speed $3c/5$ relative to the space station.

a) Determine when the two supernovae occurred according to the space station observer.

b) Suppose that the unprimed frame is that used by the space station observers. List the coordinates for the two events: supernova α occurs and supernova β occurs.

c) Using the Lorentz transformation determine the coordinates for the two events in the rocket frame.

d) According to the space station observers how much time elapses between the two supernovae?

e) According to the rocket observers how much time elapses between the two supernovae? Which occurs first?

2 Simultaneity trainthought experiment

Yvonne is midway along a train car that travels with speed $3c/5$ to the right relative to Zach, on the platform. Zach is midway between two light beacons, with blue to the left and red to the right. The blue is triggered by the back end of the train and the red by the right end of the train. According to Zach, each beacon is $4\,\text{lt}\cdot\text{ns}$ from him. He observes that the a red flash and a blue flash arrive simultaneously at his location at $t = 4\,\text{ns}$. For uniformity in the following, let Zach use the unprimed frame and Yvonne the primed frame.

a) Determine when each of the pulses was produced according to Zach. List the coordinates according to Zach for the two events: the blue flash is produced and the red flash is produced.

b) Use the Lorentz transformations to determine the coordinates for these two events according to Yvonne.

c) Consider the following events: the blue flash reaches Yvonne and the red flash reaches Yvonne. Determine the coordinates for these two events according to Yvonne.

d) Determine the coordinates for the two events of the previous part according to Zach. Does they both agree on which reaches Yvonne first? Show that the times elapsed between then are consistent with what would be obtained using time dilation.

3 Helliwell, *Special Relativity*, Problem 8-4, page 109.

4 Helliwell, *Special Relativity*, Problem 8-7, page 109.

5 Supernovae in the rocket frame

Two stars α and β are at rest with respect to each other and, in their rest frame are separated by $40c \cdot \text{yr}$. A space station, at rest relative to the stars, is midway between them. A rocket passes the space station at time $0\,\text{yr}$. At a later time according to the rocket two light pulses, indicating supernovae, arrive simultaneously at the rocket.

a) Draw a spacetime diagram indicating the trajectories of the space station, the rocket and each of the stars.

b) Indicate the two events: light arrives from α and light arrives from β at the rocket. Use this to indicate the trajectories of the two light pulses and the two events: supernova α occurred and supernova α occurred.

c) In what order do the supernovae occur according to each observer?

d) Repeat this for the situation where, according to the rocket observer, the supernovae occur simultaneously. In what order do the pulses arrive at each observer?

6 Helliwell, *Special Relativity*, Problem 7-1, page 93. You can use Lorentz transformations if they help.

a) Answer the problem parts in the text.

b) If you have not already done so, determine the coordinates of the following two events in both frames: rocket leaves and rocket arrives. Calculate the spacetime interval in both frames and verify that they are the same.

7 Helliwell, *Special Relativity*, Problem 7-10, page 93. You can use Lorentz transformations if they help. Let the unprimed frame be the tunnel/saboteur frame and the primed from the train frame.

a) Suppose that the left end of the tunnel corresponds to $x = 0$. Draw this on a spacetime diagram. Repeat for the right edge of the tunnel.

b) Suppose that $x' = 0$ corresponds to the right end of the train and that this reaches the left edge of the tunnel at $t = 0$. Draw the trajectories for the right edge, left edge and detector (midpoint of the train) on the spacetime diagram.

c) Indicate the sections of trajectory for which the left end of the train is in darkness. Do the same for the right edge.

d) Indicate the trajectory of light passing from the right edge of the train to the detector at the moment that the train first enters the tunnel. Repeat this for when the right edge leaves the tunnel. Use these extremes to indicate when the detector receives light from the right edge. Repeat this process for light from the left edge.

e) Does the detector ever receive light from both edges at the same instant? Can you resolve the paradox?

8 Helliwell, *Special Relativity*, Problem 10-6, page 142.

9 Helliwell, *Special Relativity*, Problem 10-7, page 142.

10 Helliwell, *Special Relativity*, Problem 11-2, page 142.