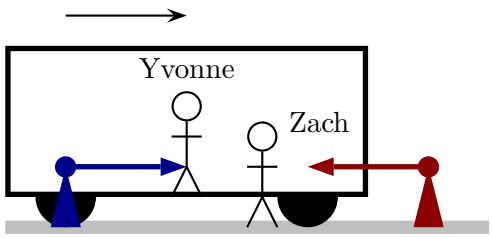
Intermediate Dynamics: Group Exercises 2

Simultaneity

1 Simultaneous events

A classic thought experiment involves two observers observing pairs of events that are produced at separate locations and asks whether or not the observers agree that the events are simultaneous or not. Consider a train that passes a platform as illustrated. The ingredients of the thought experiment are:



1. A red (on the right) and a blue light (on the left) that are stationary with respect to the platform.
2. A red on the right end of the train and a blue light on the left end of the train. *These are not really essential but simplify some of the reasoning.*
3. Two observers. Yvonne is at rest with respect to the train and midway between the ends of the train. Zach is at rest with respect to the platform and is midway between the lights.
4. Each light has a trigger which produces a pulse. The red lights produces pulses when the back end of the train is at the red light on the platform and the blue light when the front end of the train is at the blue light on the platform.

Zach observes that a red flash and a blue flash arrive at him simultaneously.

a) Suppose that the distance between platform lights according to Zach is d and that the red pulse arrives at time $t_{\text{Z red arriv}}$. Determine an expression for the time, $t_{\text{Z red prod}}$, at which the red pulse is produced according to Zach.

b) Repeat the above for the blue pulse. Determine an expression for the time between when the pulses were produced according to Zach, $\Delta t_{\text{Z prod}} = t_{\text{Z red prod}} - t_{\text{Z blue prod}}$.

c) According to Zach, were the flashes produced simultaneously?

d) According to Zach, were is Yvonne at the time at which the flashes were produced? According to Zach, what is the order in which the pulses arrive at Yvonne?

e) According to Zach in what order do the pulses arrive at Yvonne? This is the same as the order in which Yvonne observes their arrival.

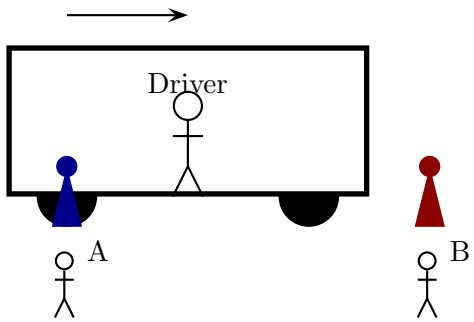
f) According to Yvonne, the length of teh train is D. How far has each pulse traveled according to her?

g) Assuming that Einstein's postulates are correct, what does Yvonne conclude about the order in which the pulses were produced? Try to assess this by determining an expression for $\Delta t_{\text{Y prod}} = t_{\text{Y red prod}} - t_{\text{Y blue prod}}$.

h) Do the observers agree that the pulses were produced simultaneously?

2 Train robbers

A classic situation in special relativity involves collaborating train robbers. The two robbers are stationary with respect to each other and each is equipped with a cannon that is adjacent to a train that passes to the right. If a robber fires a cannon and the train is adjacent then it immediately hits the train. The ingredients of this are:



1. The robbers are distance $80\,\mathrm{lt}\cdot\,\mathrm{ns} = 80c\,\mathrm{ns}$ apart as observed in their rest frame.
2. The length of the train is $100\,\mathrm{lt}\cdot\,\mathrm{ns} = 100c\,\mathrm{ns}$ as observed in its rest frame.
3. By shear luck the robbers fire their cannons simultaneously as observed in their rest frame at the instant that the right end of the train has just passed A.

Answer the following.

a) According to classical physics will one of the robbers hit the train?

b) A policeman observes this and remembers some special relativity. What does the policeman conclude about the length of the train as observed from the robber rest frame compared to the train rest frame?

c) The policeman reasons that if the train travels fast enough relative to the robbers, then it will evade both cannons. What is the minimum speed required to do so?

d) Suppose that the train travels at this minimum speed. A mastermind of the robbers considers the situation from the perspective of the train. From this frame what would the distance between the robbers be? What would the mastermind conclude, in terms of the cannonballs hitting? Is the conclusion the same as that for the policeman?

e) If one observer observes that the train is hit then this event must occur according to all other observers. Can you resolve the apparent paradox?