Modern Physics

Week 2 - Tutorial 1-3

07^{th} September, 2012

1. Lorentz Transformations at work: Consider a railway man standing at the middle of a freight car of length $2L$. He flicks on his lantern and a light pulse travels out in all directions with the velocity c. Find the time of arrival of the light pulse at each end of the freight car in the following two frames:
i. Frame of the railway man standing at the middle of the freight car.
ii. Frame of a man standing outside the freight car, whose frame is coincident with railway man's frame initially, before the train starts to move with speed v in his frame.

2. Simultaneity of events: For any two events A and B, can we always go to frame where they are simultaneous?

3. Speed of light in moving media: The velocity of light in matter is less than c. The index of refraction, n, is used to specify the speed in a medium:

$$n = \frac{c}{velocity\ of\ light\ in\ the\ medium}$$

$n = 1$ corresponds to empty space; in matter $n > 1$. The slowing can be appreciable: for water $n = 1.3$.
The problem is to find the speed of light through a moving liquid. For instance, consider a tube filled with water. If the water is at rest, the velocity of light in the water with respect to the laboratory is $u = c/n$. What is the speed of light when the water is flowing with speed v?

4. Save Julius Caesar: Julius Caesar was murdered on March 15 in the year 44 B.C. at the age of 55 approximately 2000 years ago. Is there some way we can use the laws of relativity to save his life?
Let Caesar's death be the reference event, labelled O: $x_o = 0$, $t_o = 0$. Event A is you reading this exercise. In the Earth frame the coordinates of event A are $x_A = 0$ light-years, $t_A = 2000$ years. Simultaneous with event A in your frame, Spaceship D cruising the Andromeda galaxy sets off a firecracker: event B. The spaceship moves along a straight line in space that connects it with Earth. Andromeda is 2 million light-years distant in our frame. Compared with this distance, you can neglect the orbit of Earth around Sun. Therefore, in our frame, event B has the coordinates $x_B = 2 * 10^6$ light-years, $t_B = 2000$ years. Take Caesar's murder to be the reference event for the spaceship too ($x'_o = 0, t'_o = 0$).

i. How fast must the spaceship be going in the Earth frame in order that Caesar's murder is happening NOW (that is, $t'_B = 0$) in the spaceship rest frame? Under these circumstance is the Enterprise moving toward or away from Earth?

ii. Draw a spacetime diagram for the Earth from that displays event O (Caeasar's death), event A (you reading this exercise), event B (firecracker exploding in Andromeda), your line of NOW simultaneity, the position of the spaceship, the worldline of the spaceship, and the spaceship NOW line of simultaneity. The spacetime diagram need not be drawn to scale.

iii. In the spaceship frame, what are the x and t coordinates of the firecracker explosion?

iv. Can the spaceship firecracker explosion warn Caesar, thus changing the course of Earth history? Justify your answer.