Physics 24 Problem Set 4

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due Monday, February 6

Please make your work neat, clear, and easy to follow. It is hard to grade sloppy work accurately. Generally, make a clear diagram, and label quantities. Derive symbolic answers, and then plug in numbers after a symbolic answer is available.

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1. In the table below, the time (in nanoseconds) and the position in x (in meters) of a variety of pairs of events in an 'unprimed' reference frame are given. For reference, the speed of light is $c = 0.3\,\mathrm{m/ns}$.

   (a) Compute and fill the third column with the invariant interval (I) between the events in nanoseconds^2.

   (b) For timelike (spacelike) intervals, put T (S) in the fourth column. If the interval is on the lightcone, put in 'LC'.

   (c) When viewed from a particular different inertial frame, designated the 'primed' frame, the pair of events may be either at the same point in space but at different times, or simultaneous but separated in space, when the invariant interval either is timelike or spacelike respectively. Evaluate the velocity of that intertial frame, and put the velocity relative to the speed of light β in the fifth column.

   (d) In the sixth and seventh columns, place the values of the time and position of each of the events, (t_1', x_1') and (t_2', x_2'), as viewed in the reference frame described in the previous part.

   (e) In the eighth column, put whichever quantity is non-zero, $\Delta t' = t_2' - t_1'$ or $\Delta x' = x_2' - x_1'$.

   (f) In the ninth column, evaluate $\sqrt{I}$ or $c\sqrt{-I}$, whichever is appropriate; do you get the same value as in the eighth column?

   (g) In the last column, answer the question: can an event that happens at (t_1, x_1) influence what happens at (t_2, x_2)? In particular, are there any cases where a second event that occurs (in one frame) *after* the first event can actually influence the first event?

(t_1, x_1)	(t_2, x_2)	$I(\mathrm{ns}^2)$	T/S/LC	β	(t_1', x_1')	(t_2', x_2')	$\Delta t'$ or $\Delta x'$	$\sqrt{I}$ or $c\sqrt{-I}$	Y/N
(0,0)	(1,0.2)								
(0,0)	(1,0.3)								
(0,0)	(1,0.4)								
(5,5.2)	(4,5)								
(5,5.4)	(4,5)								

2. A polevaulter has a pole of length $L = 12$ meters, when at rest, and the vaulter runs at a speed of $\beta = 2\sqrt{3}/3 = 0.943$, relative to the speed of light. They run into a barn of length $L = 8$ meters. Both an observer at rest in the barn (the unprimed frame) and the polevaulter (the primed frame) set their clocks at $t = t' = 0$ when the tip of the pole just enters the barn, which is also when the front barn door opens. The origin of the unprimed coordinate system, $x = 0$ is the front barn

door, and the origin of the primed coordinate system, $x' = 0$, is the front tip of the pole. Find the time and space coordinates of the following events, in both coordinate systems, and plot them on two separate spacetime maps, one for the barn system, and one for the polevaulter system:

(a) **A**, when the front tip of the pole enters the barn and the barn front door opens.

(b) **B**, when the rear tip fo the pole enters the barn through the front door and the front door close.

(c) **C**, when the front tip of the pole exits the back door and the back door opens.

(d) **D**, when the rear tip of the pole exits the barn through the back door and the back door closes.

What is the order of the events that the observer at rest with respect to the barn sees?

3. A nutcracker is shown in Fig. 1. The hammer and anvil that constitute the nutcracker are shown at rest in part (a) of the figure, with a nut. Someone zealous and hungry pushes the hammer of the cracker so hard that it achieves a velocity $\vec{u}$ so near to the speed of light that the hammer is length-contracted, as shown in part (b) of that figure. The anvil portion of the nutcracker is impossible to move. It looks like the nut will never get cracked!

   (a) Evaluate β, the speed of the hammer, relative to the speed of light.

   (b) What happens when the brim on the hammer hits the upper surface of the anvil, and the brim stops? Does the nut ever get cracked?

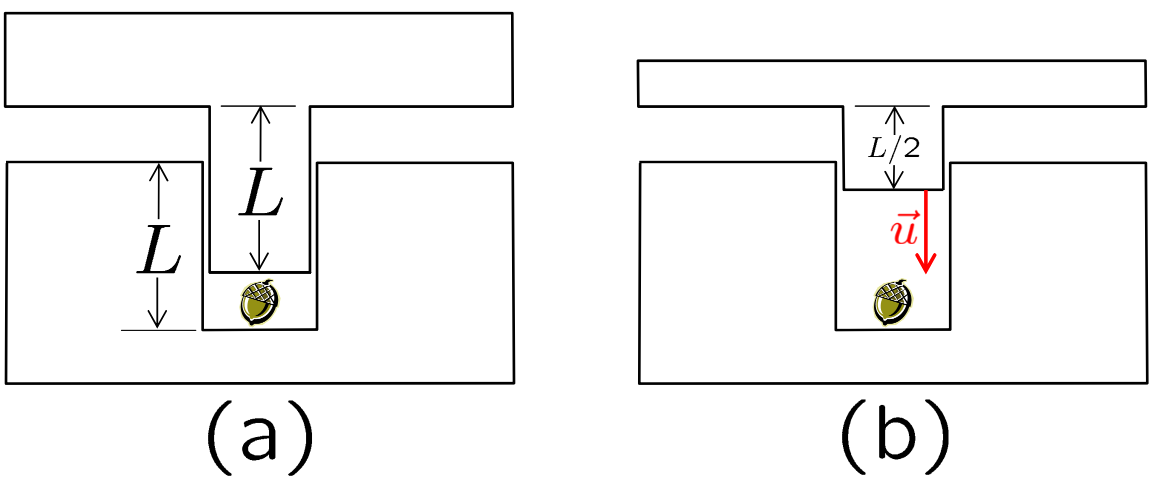

Figure 1: For use in Problem 3.

4. Fred goes from event A at $(t_A, x_A) = (0, 0)$ to event D at $(t_D, x_D) = (100\,\text{ns}, 10\,\text{m})$ with constant velocity and stops. George, on the other hand, moves with constant velocity between a series of events, and at each event, he accelerates. George also starts at event A, but then goes to event B at $(t_B, x_B) = (20\,\text{ns}, 5.6\,\text{m})$, accelerates, then moves with constant velocity to event C $(t_C, x_C) = (80\,\text{ns}, 15\,\text{m})$, accelerates, then moves to event D at at $(t_D, x_D) = (100\,\text{ns}, 10\,\text{m})$ and stops.

   (a) Make a spacetime map showing the two 'world lines' of Fred and George.

   (b) How much time passes on Fred's watch, and how much time passes on George's watch, as they go from event A to event D?

5. A women running by you at $\beta = 0.95$ shoots an arrow in the same direction that she is running. She sees the arrow going with $\beta = 0.95$. With what β_A do you see the arrow moving?