In the bottom diagram we examine two reference frames ('trains') that are moving relative to each other. We do this from a third frame that is "between" the other two so from our third frame both trains have the same speed but are moving in opposite directions. Note from our point of view the clocks in the various train cars read different values (the circled numbers). The clocks on each train are synchronized according to observers on the trains – relativity says synchronized clocks appear unsynchronized if in motion. (Note: this is ~~not~~ in addition to time dilation – these clocks maintain a constant offset even as they run slow). If we want to understand what things look like to (say) the top ~~frame~~ train we must pull together the instants that the people on that train call "Now". Look at the top train time of 2: we learn that A' is next to A & B' & D are together & the train has past C'

A'   B'   C'

A B C D E

clearly the cars in the bottom train are $\frac{1}{3}$ the length of my cars. Similar time = 1:

A'   B'   C'

A B C D E

similar time = 0

A'   B'   C'   D'

A B C D E

If we view from bottom train @ $t=2$

A' B' C' D' E'

C D E

@ $t=1$

A' B' C' D' E'

C D E

3 moving cars take up same length as one of my cars.

If — still viewing from bottom train — we view clocks in top train: it takes 3 sec [−2 to +1] for A': $2 \to 3$

" " " " [−1 to 2] for B': $1 \to 2$

" " " " [0 to 3] for C': $0 \to 1$

Those moving clocks are running at $\frac{1}{3}$ normal rate!

Much the same when the top train views bottom train clocks

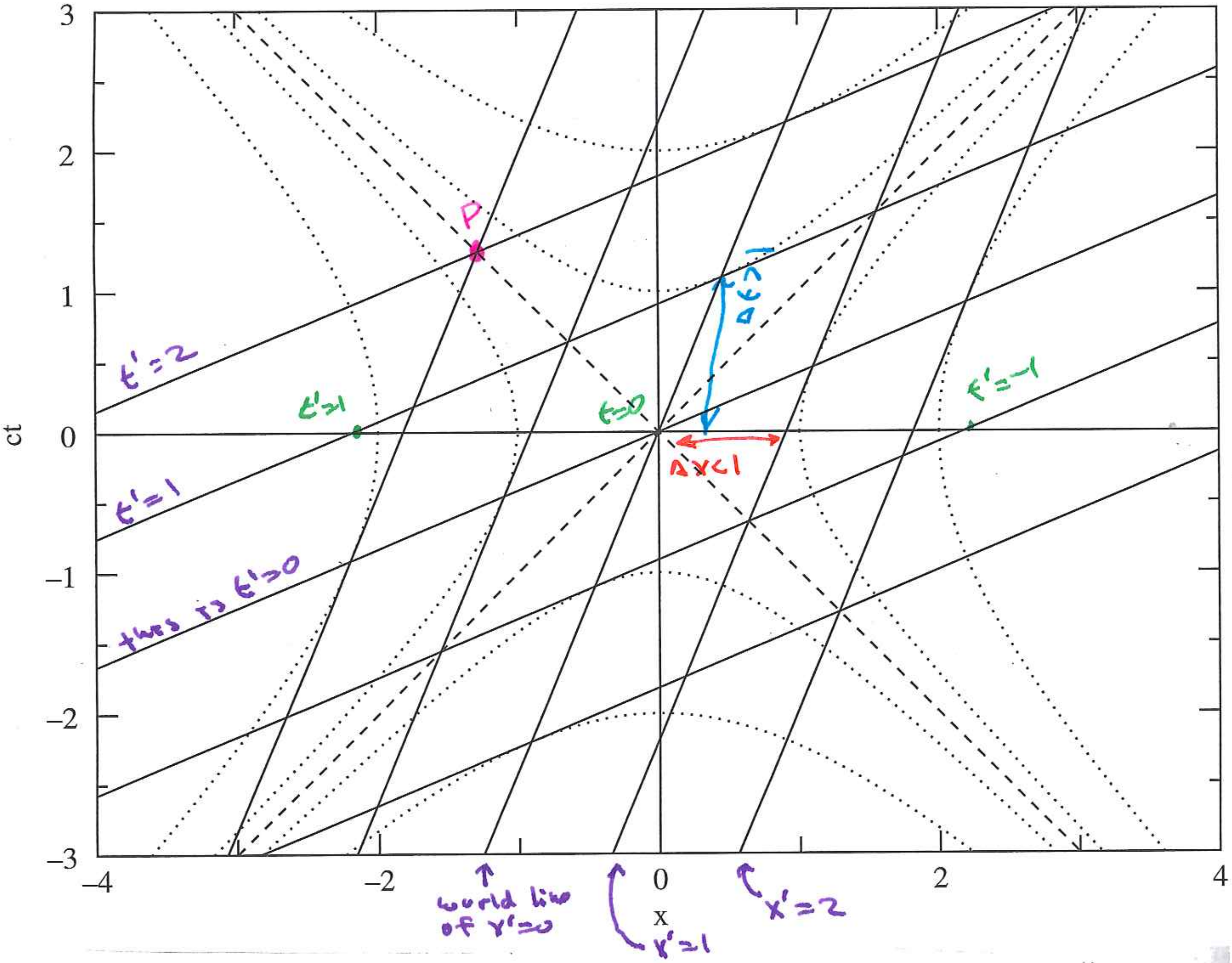
it takes 3 sec [−2 to 1] for E: $2 \to 3$

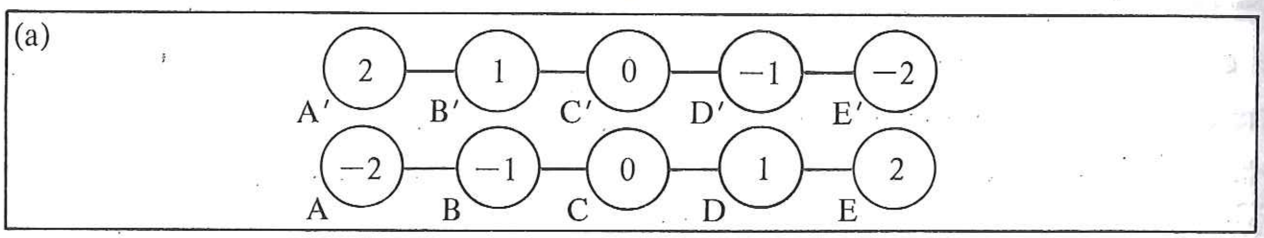
" " " " [−1 to 2] for D: $1 \to 2$

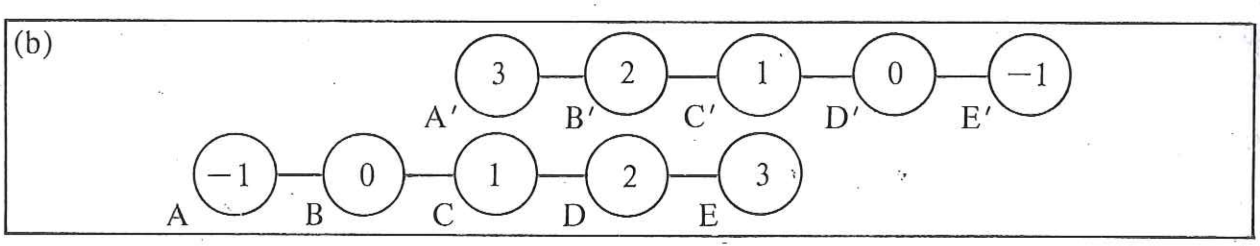
" " " " [0 to 3] for C: $0 \to 1$

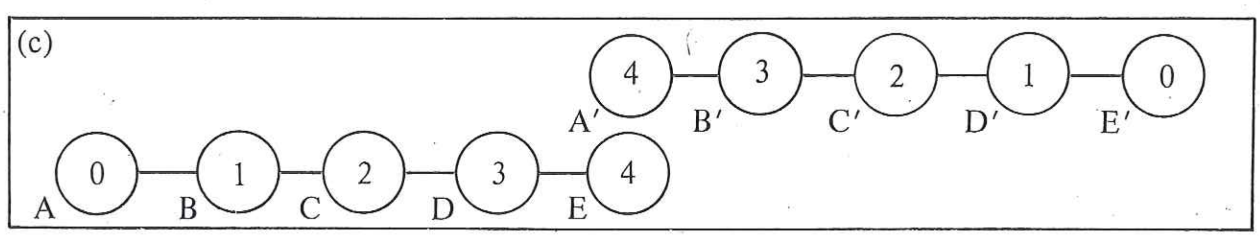
Upshot: Relativity of sychronization plays a big role in Lorentz contraction & time dilation.

Minkowski Diagram









Minkowski: note that every event in Universe has (x,t) coordinates & (x',t') coordinates — Lorentz transformation matrix allows you to calculate one set of coordinates given the other. The lines "$t'=0$", "$t'=1$", "$t'=2$" are ~30° slopes ⁄ and labeled lhs. The steeply sloped lines / (labeled "$x'=0$", "$x'=1$", "$x'=2$") are labeled below the plot. The basic (x,t) coordinates can be read from the normal axes labels.

The point P: $(x',t') = (-2,2)$ $(x,t) \approx (-1.4, 1.4)$

note units such that $c=1$ eg $[x]$ = lightyears $[t]$ = years

The ±45° dashed lines are "light cones" ie equation $x = \pm ct$

Consider a clock that sits at $x'=0$. As it ticks off one unit it moves from $(x,t) = (0,0) \rightarrow (.5, \underbrace{1.1})$

note that this is longer than $\Delta t'$ — time dilation!

consider a "meter stick" in the frame' that stretches from $x'=0$ to $x'=1$. The world lines of the ends of this stick are a pair of lines //

note that at the instant $t=0$ if we locate these ends we get $(x,t) = (0,0)$ & $(\underbrace{.9}, 0)$

note that this is less than 1: Lorentz contraction.

if at $t=0$ we look at the clocks in frame'

see the one at $(x,t) = (-2.2, 0)$ reads $+1$

$= (0,0)$ reads 0

$= (2.2, 0)$ reads -1

} the leading clock on a moving frame reads a smaller value.