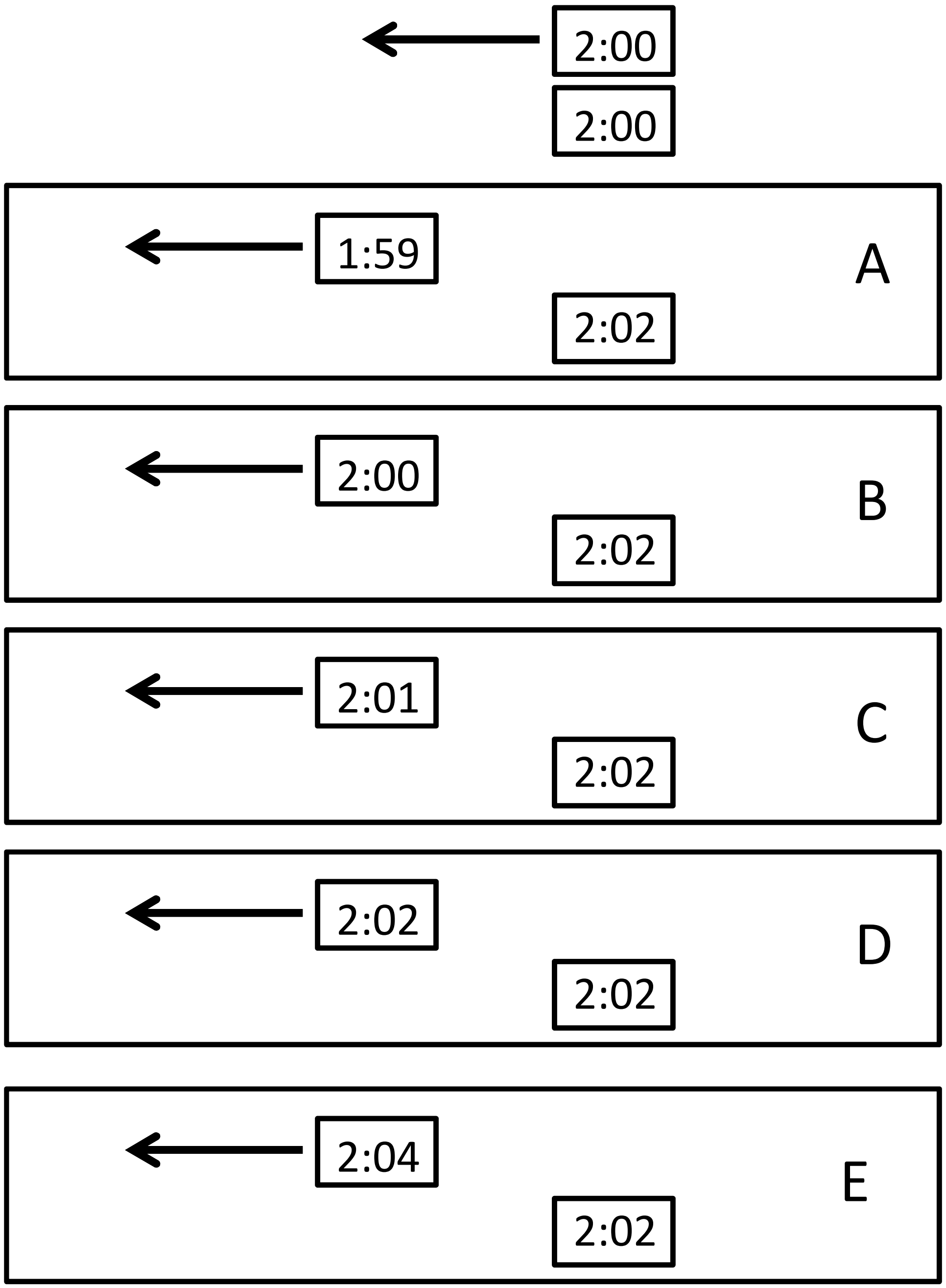
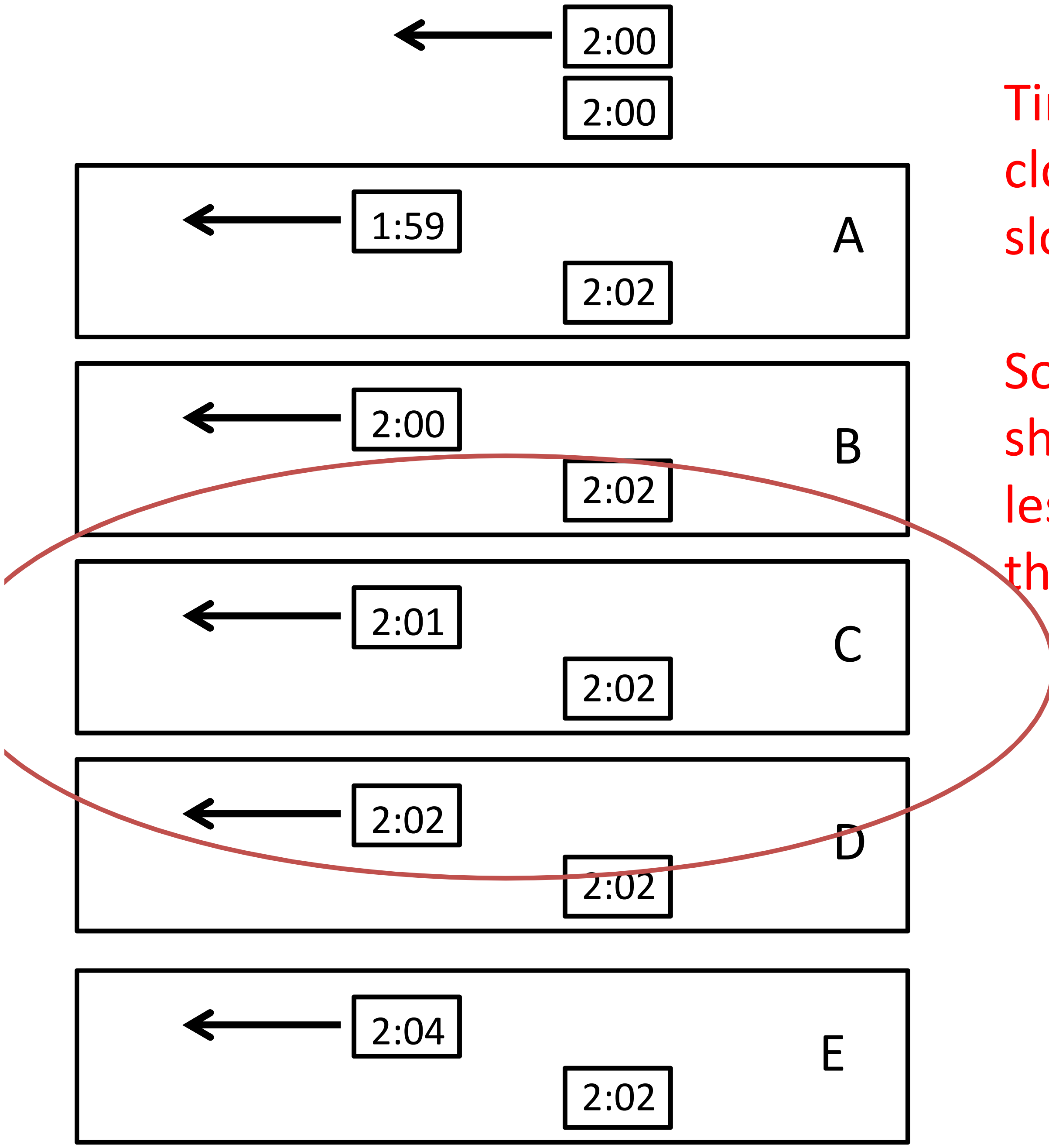


Two identical clocks are set to the same time as one passes the other at high velocity (as shown in the top figure). Which of the other figures represents a possible observation of the clocks at some later time in the frame of the fixed clock?

Assume the times are exact.



Time dilation: moving clock appears to run slower (but still forward).

So time on moving clock should read something less than 2:02 but greater than 2:00.

Muons are unstable elementary particles with a half-life of approximately $\tau = 2 \times 10^{-6}$s. If a muon is produced in the upper atmosphere travelling at speed v = 4/5c, how far would we expect it to travel before decaying?

A) v τ

B) Less than v τ

C) Greater than v τ

D) We will never see it decay

EXTRA: Calculate precisely how far we expect it to travel before decaying.

Muons are unstable elementary particles with a half-life of approximately $\tau = 2 \times 10^{-6}$s. If a muon is produced in the upper atmosphere travelling at speed v = 4/5c, how far would we expect it to travel before decaying?

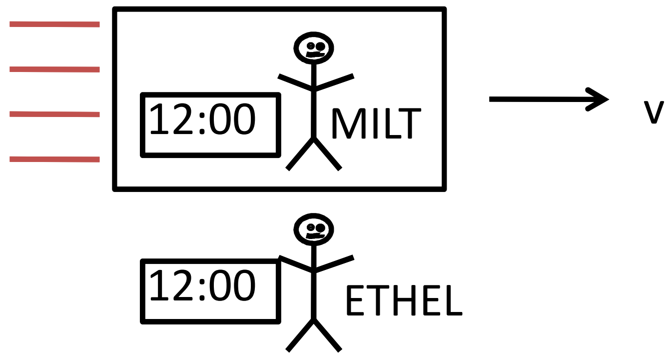
A) v τ

B) Less than v τ

C) Greater than v τ

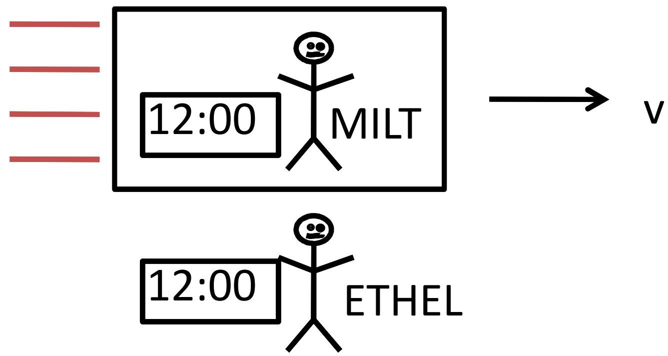
D) We will never see it decay

We see the muon's "clock" run slow, so it takes time $\tau\,\gamma$ in our frame of reference before the muon reaches its half life. Thus, the muon travels a distance $\tau\,\gamma\,v = (2\times10^{-6}\text{s})\times(5/3)\times(4/5\times3\times10^{8}\text{m/s})$ which is about 800m.



Milt and Ethel's clocks both read noon when they pass each other. According to Milt, when his clock changes to 12:01, Ethel's clock will read:

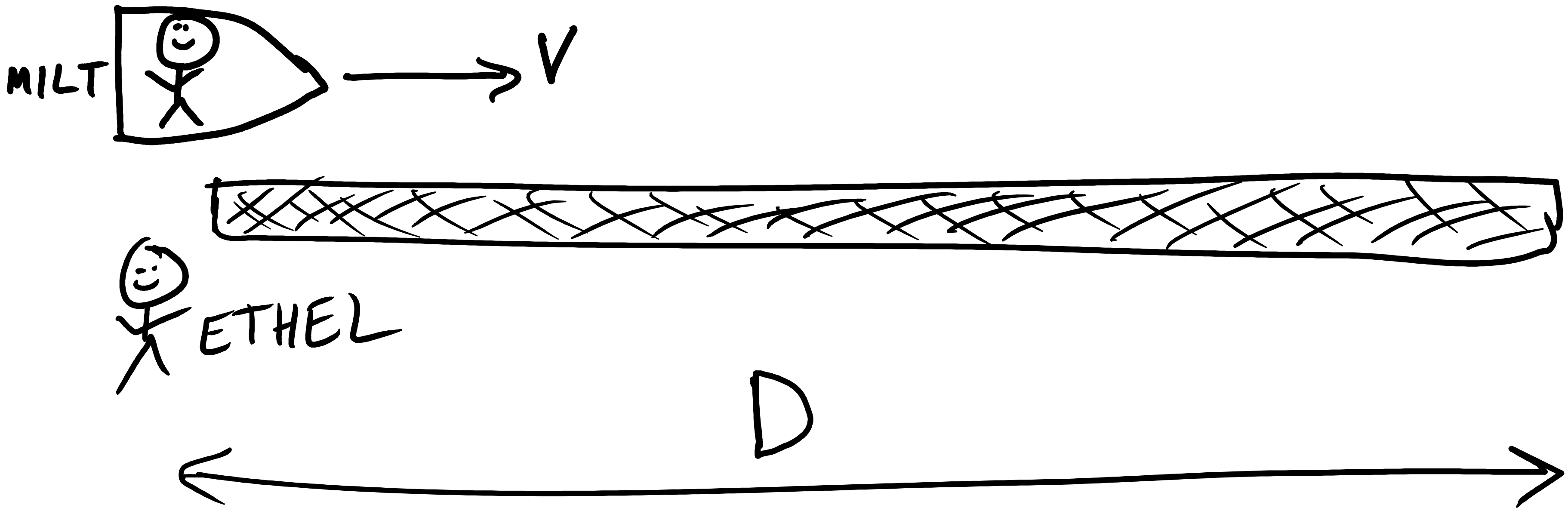
A) 12:01 exactly
B) An earlier time
C) A later time



Milt and Ethel's clocks both read noon when they pass each other. According to Milt, when his clock changes to 12:01, Ethel's clock will read:

A) 12:01 exactly
B) An earlier time
C) A later time

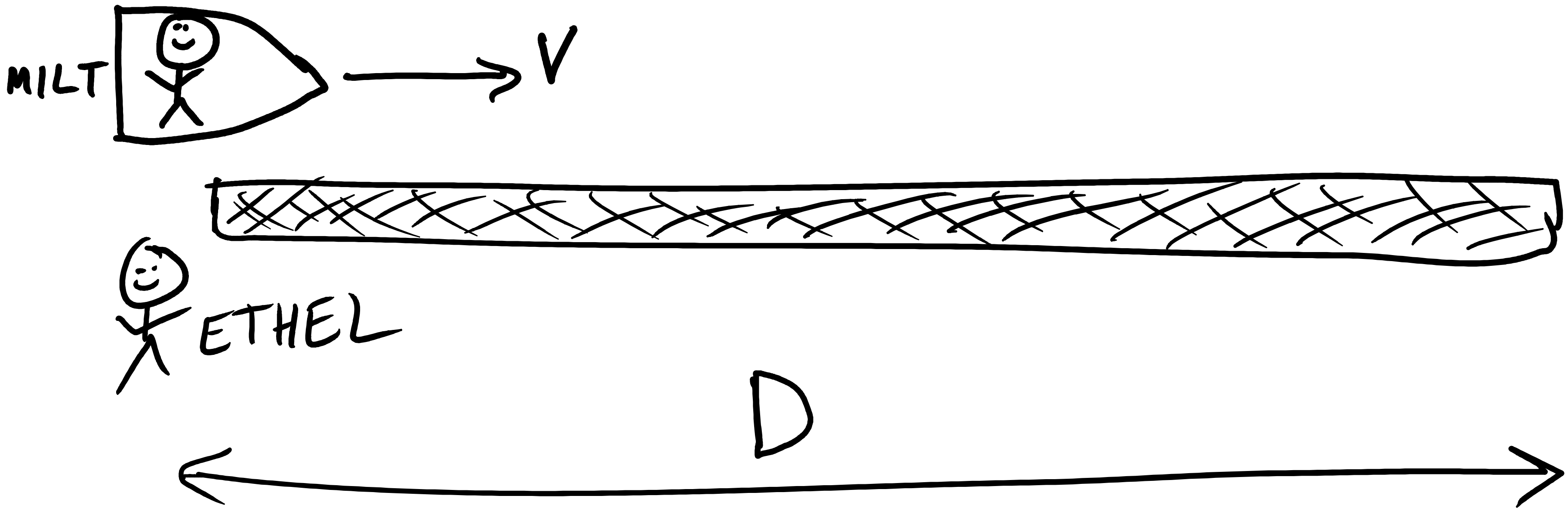
Milt sees Ethel moving, so he sees her clock running slow. So when his clock reads 12:01, he (or other observers in his frame of reference) will observe that less than one minute has passed on Ethel's clock.



Milt's and Ethel's clocks both read time 0 in the picture shown. In this same frame of reference (i.e. Ethel's) what do their clocks read when Milt reaches the far end of the long object?

A) Ethel's clock reads D/v and Milt's clock reads D/(v γ)
B) Ethel's clock reads D/(v γ) and Milt's clock reads D/v
C) Ethel's clock reads D/v and Milt's clock reads D γ /v
D) Ethel's clock reads D γ /v and Milt's clock reads D/v
E) Both clocks read D/v

Extra: In Milt's frame of reference, the object is passing by Milt at speed v. How could Milt figure out how the length of the object?

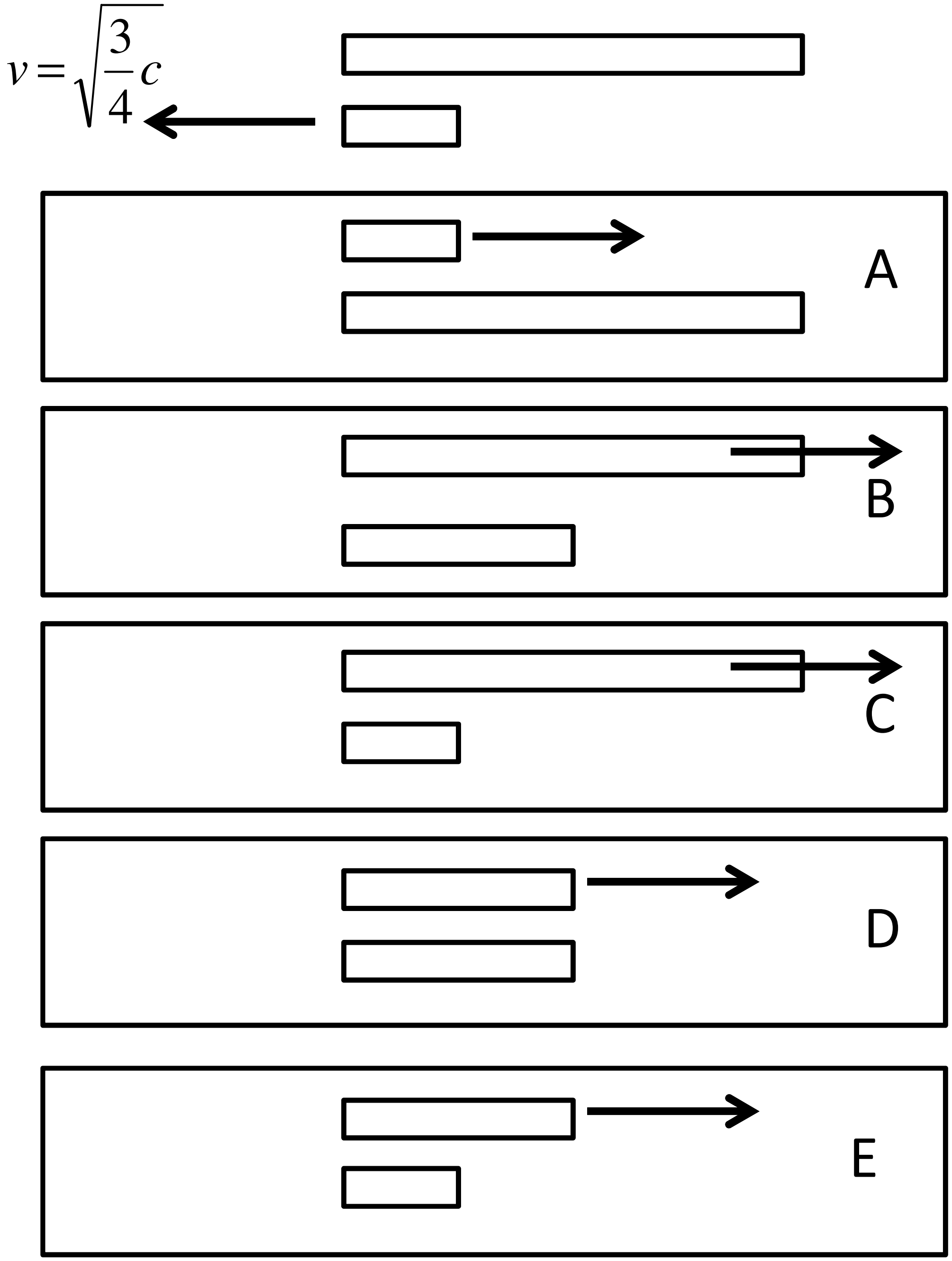


Milt's and Ethel's clocks both read time 0 in the picture shown. In this same frame of reference (i.e. Ethel's) what do their clocks read when Milt reaches the far end of the long object?

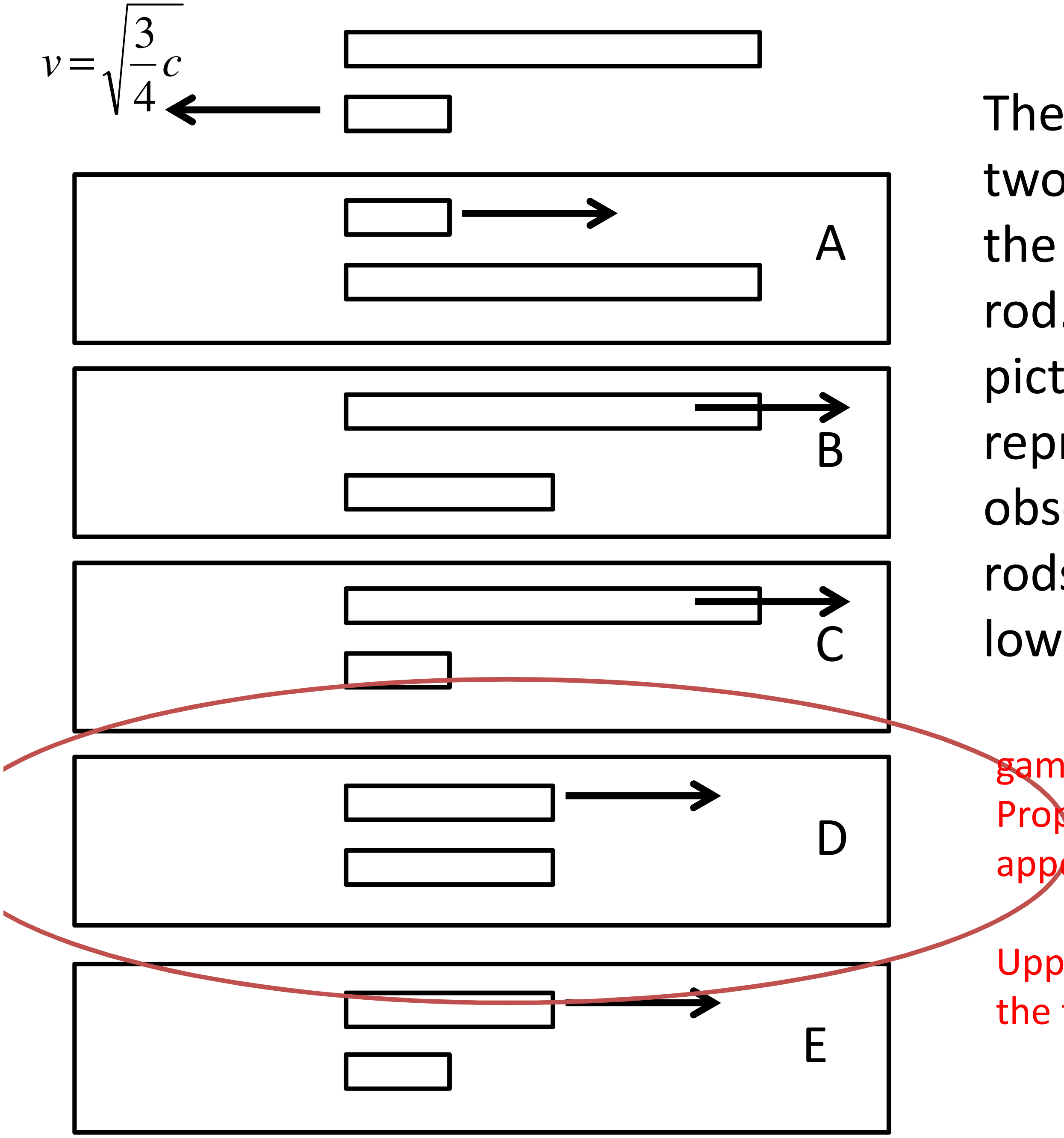
A) Ethel's clock reads D/v and Milt's clock reads D/(v γ)

In the frame of the picture, we just use the usual time = distance / speed. Ethel observes Milt's clock to run slow, so the time on Milt's clock when he reaches the end is less than Ethel's time by a factor of gamma.

Extra: to determine the length of the object (in his frame of reference, Milt can multiply its speed by the time it takes to pass him).



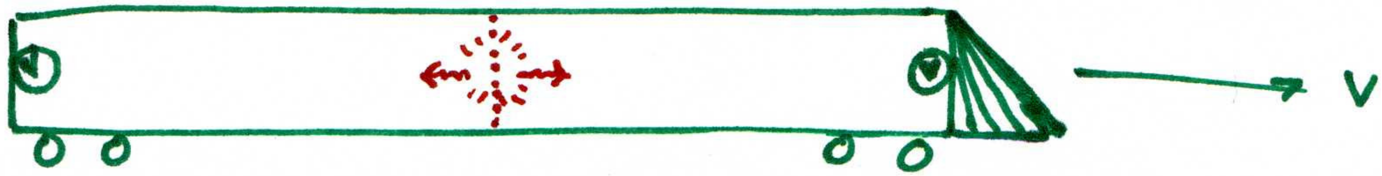
The top picture shows two rods, as observed in the frame of the upper rod. Which of the pictures below it represents an observation of the same rods in the frame of the lower rod?



The top picture shows two rods, as observed in the frame of the upper rod. Which of the pictures below it represents an observation of the same rods in the frame of the lower rod?

gamma is 2, so the the lower ruler's Proper length is twice as long as it appears in the 1st picture.

Upper ruler will appear half as long in the frame of the lower ruler.

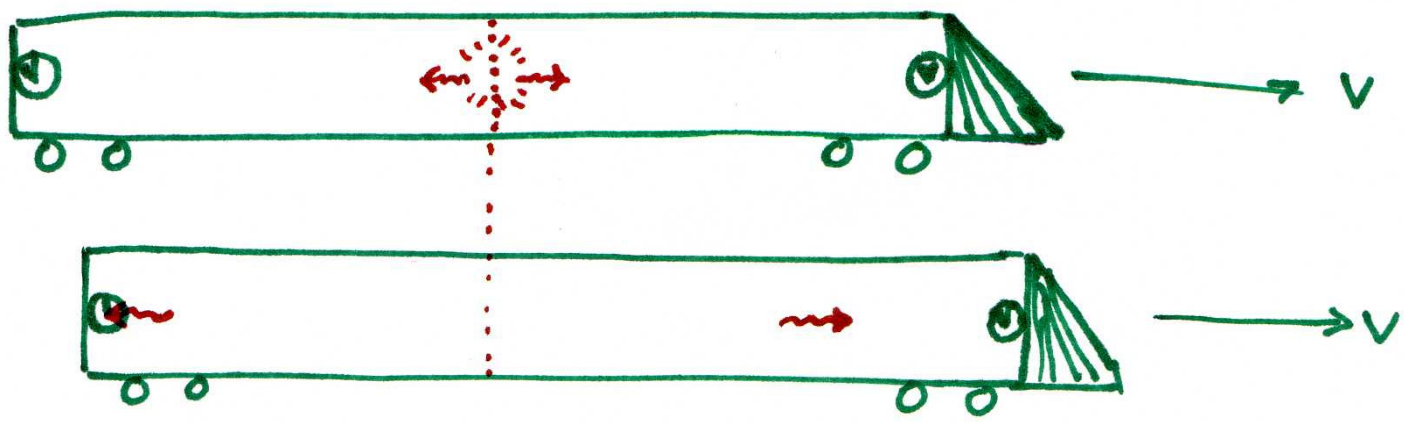


A light flashes exactly in the middle of a train moving along a track. Observers in the train measure the light to hit each end of the train at exactly noon. According to observers on the track:

A) Light hits the front of the train before the back of the train.
B) Light hits the back of the train before the front of the train.
C) Light hits the front and back at the same time.

Extra: Do people on the track observe the clocks at either end of the train to read the same time?

If not, which one appears to read an earlier time and how much do the times differ by?

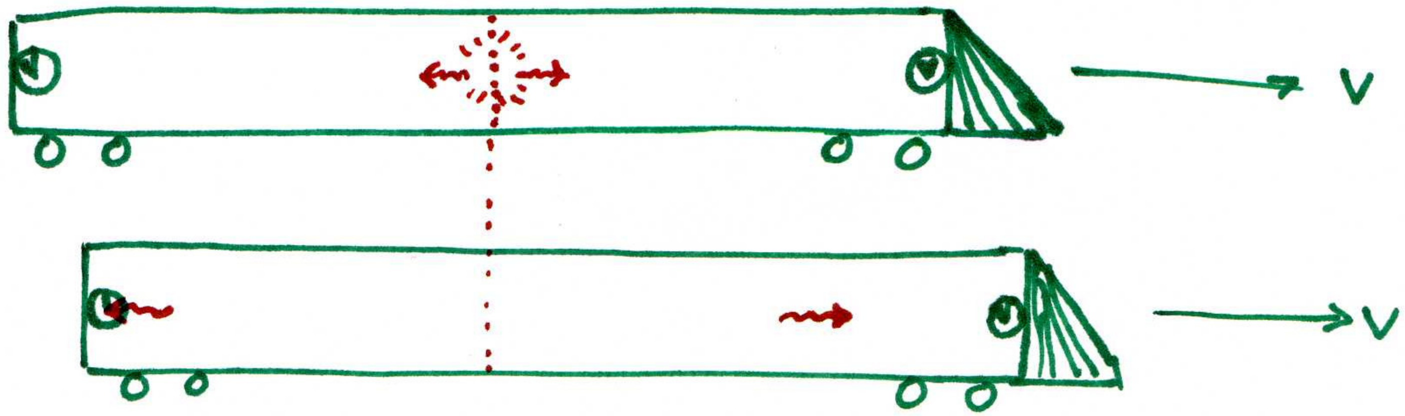


Answer:

D) Light hits the back of the train before the front of the train.

According to observers on the track, when the light hits the back of the train, the front of the train is further from the place where the light flashed, so the light cannot have reached it yet.

In the second picture, the back clock reads noon, but the front clock reads earlier than noon, since the light hasn't hit it yet.



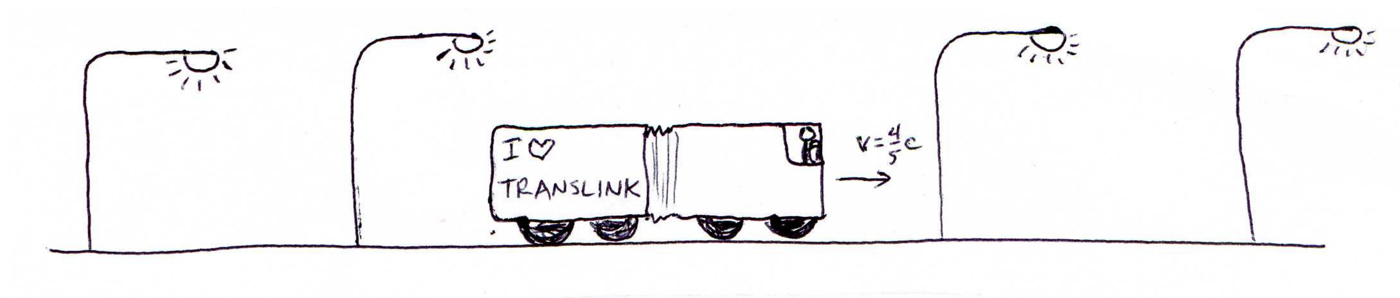
Answer:

D) Light hits the back of the train before the front of the train.

According to observers on the track, when the light hits the back of the train, the front of the train is further from the place where the light flashed, so the light cannot have reached it yet.

In the second picture, the back clock reads noon, but the front clock reads earlier than noon, since the light hasn't hit it yet.

Earlier by $v L/c^2$ to be precise.



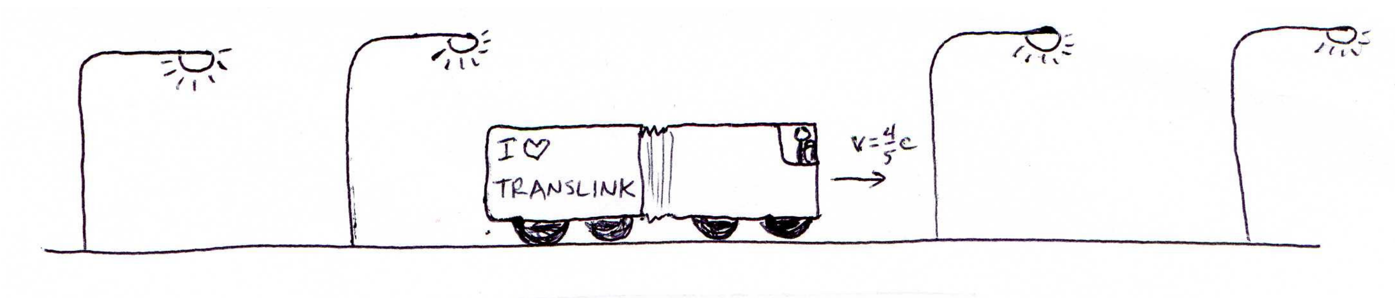
The 99 B-Line bus travels down Broadway Street at speed 4/5c. At 7:00pm, streetlights on Broadway all turn on simultaneously (in the frame of the street). In the reference frame of the bus, the streetlights ahead of the bus turn on:

A) At the same time as the streetlights behind the bus

B) After the streetlights behind the bus

C) Before the streetlights behind the bus

D) There are way too many people on the bus and there is no way to tell which lights come on first since you can't see out any of the windows.



The 99 B-Line bus travels down Broadway Street at speed 4/5c. At 7:00pm, streetlights on Broadway all turn on simultaneously (in the frame of the street). In the reference frame of the bus, the streetlights ahead of the bus turn on:

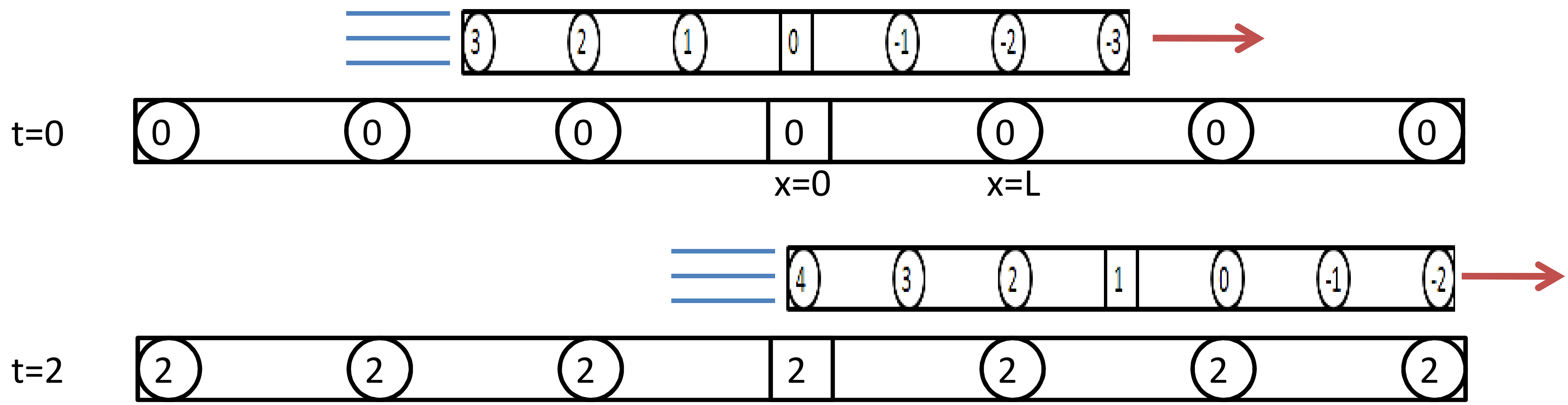
A) At the same time as the streetlights behind the bus

B) After the streetlights behind the bus

C) Before the streetlights behind the bus

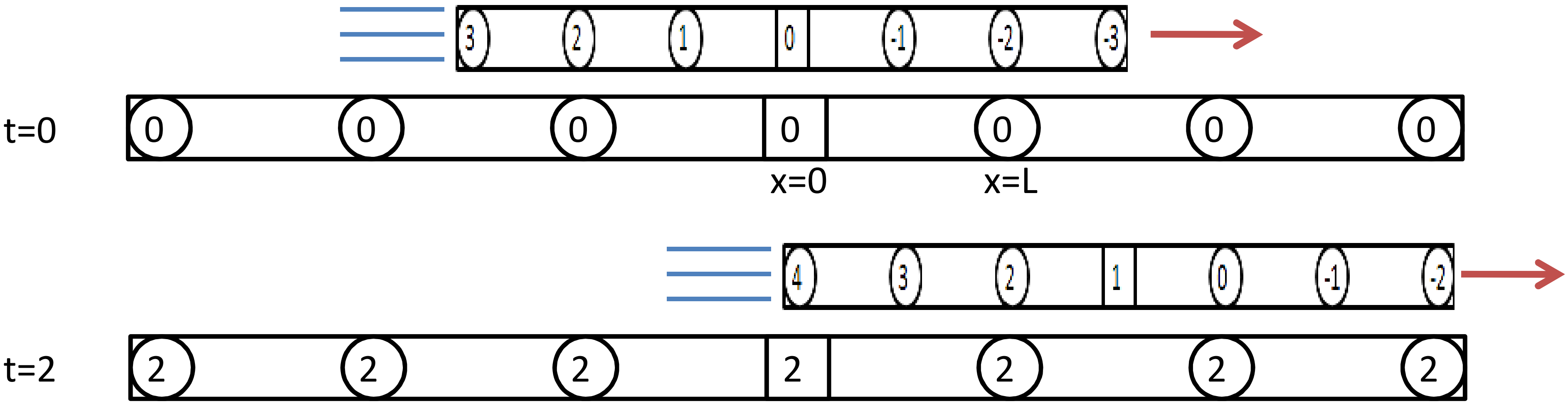
D) There are way too many people on the bus and there is no way to tell which lights come on first since you can't see out any of the windows.

If (x,t) are the coordinates of an event in the frame of the street, the time in the frame of the bus is $t' = \gamma\,(t - v/c^2 x)$. The time t is the same for all the lights turning on, but the position x is larger in front of the bus, so these lights turn on at smaller t' (i.e. before)



A firecracker explodes at position x=2L and time t=2 in the frame of the lower ruler. Where and when does this event occur in the frame of the upper ruler?

A) x'=2L, t'=0
B) x'=4L, t'=1
C) x'=L, t'=1
D) x'=L, t'=0
E) x'=L, t'=4



A firecracker explodes at position x=2L and time t=2 in the frame of the lower ruler. Where and when does this event occur in the frame of the upper ruler?

A) x'=2L, t'=0

B) x'=4L, t'=1

C) x'=L, t'=1

D) x'=L, t'=0

E) x'=L, t'=4

Wonder Woman and Batman set their alarm clocks to ring at 8:00 and 8:01 respectively. Superman is flying at $v=3/5c$ relative to the clocks. What is the time interval between the alarms in Superman's frame of reference?

A) 1 minute

B) 1.25 minutes

C) 0.8 minutes

D) Not enough information to answer

E) The principle of relativity does not apply to superheroes as they have the power to be in several different reference frames at once. The time interval that Superman observes can be anything he wants it to be.

Wonder Woman and Batman set their alarm clocks to ring at 8:00 and 8:01 respectively. Superman is flying at v=3/5c relative to the clocks. What is the time interval between the alarms in Superman's frame of reference?

D) Not enough information to answer

To use time dilation, the two events must be *at the same place* in one frame. Then we can say that these events will appear to be further apart in time to an observer moving relative to that frame.