

EXERCISE

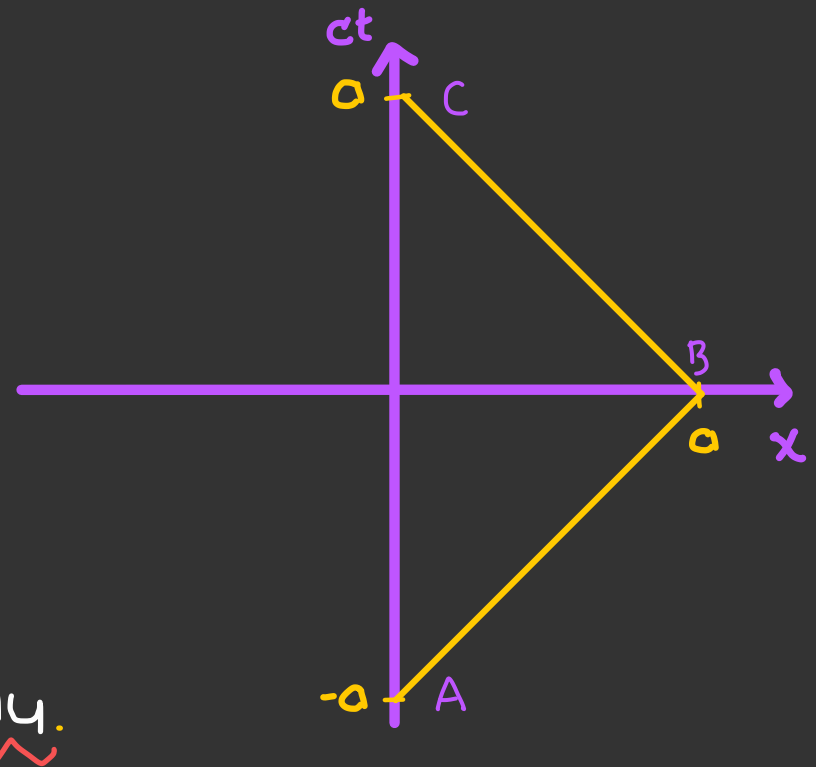
Draw the spacetime diagram for the following STAR WARS cut scene

- A. At time $t = -a$, Han Solo shot his laser gun along the x -axis
- B. The laser hits a mirror at time $t = 0$
- C. Naturally, the laser beam returns, killing Han unceremoniously.

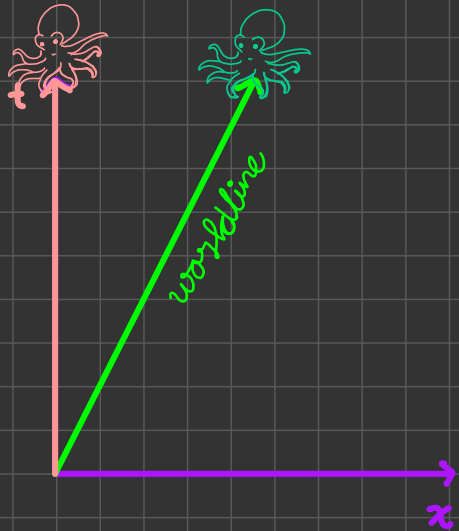
A LOST HOPE

Solⁿ

| EVENT | | |
|-------|------|--|
| x' | t' | |
| 0 | $-a$ | Shoots the laser gun |
| a | 0 | light hits a mirror |
| 0 | a | light returns to its initial position and kills Han. |



TWO OCTOPI



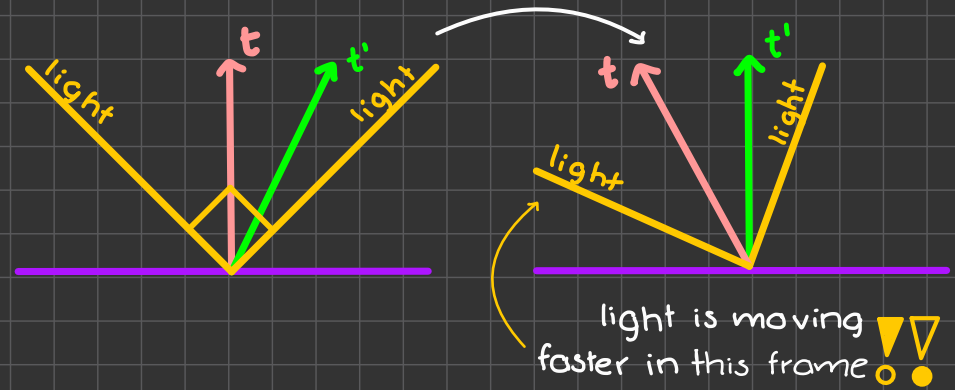
1st We have come to the conclusion that both frames are equally VALID

=> Where do we put the coordinate axes of the second octopus (t' , x')?

First try . just do a rotation!

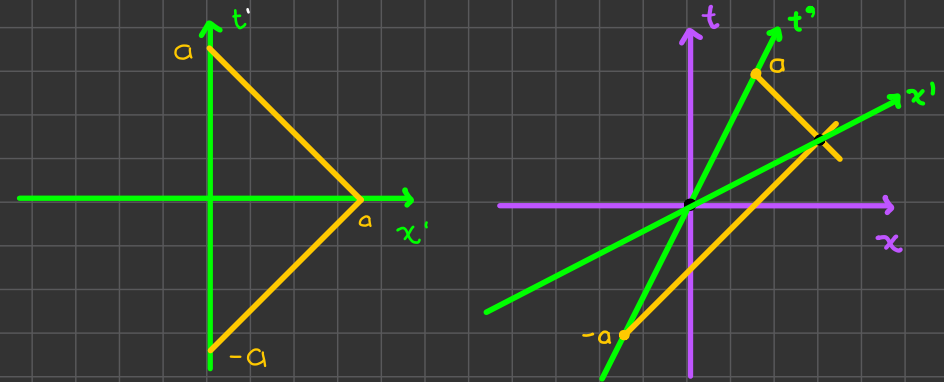


What about Jagger's principle?

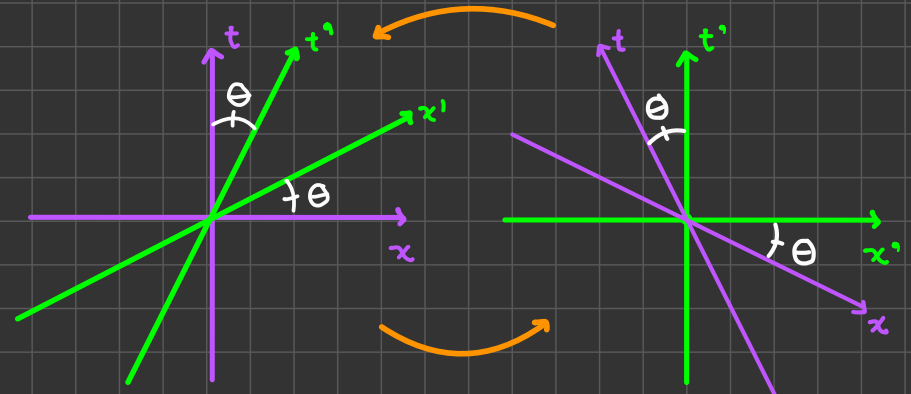


light is moving faster in this frame !!!

Let's use the Han's misfortune to determine x' .

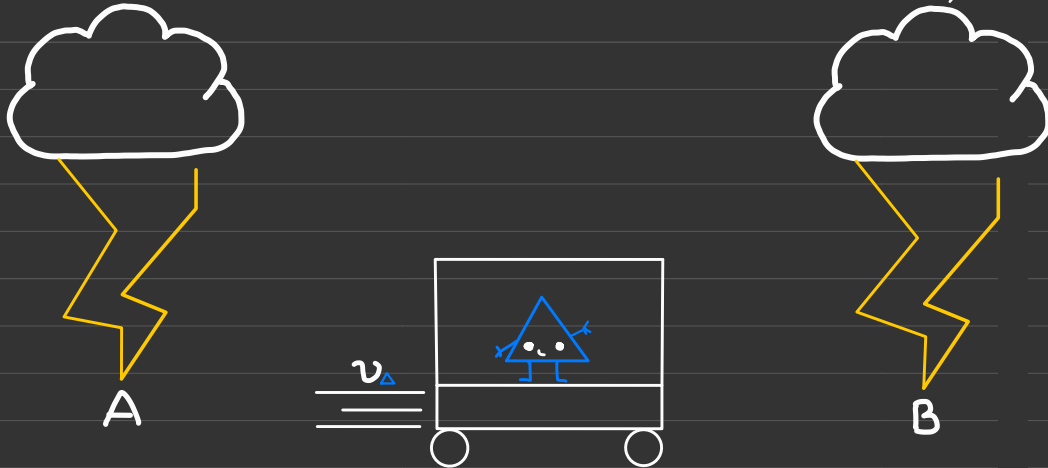


In fact, now we can describe both reference frames!



one more
THOUGHT
EXPERIMENT

(Of course we need a train car at least!)



TWO lightnings
stroke
at the same time!

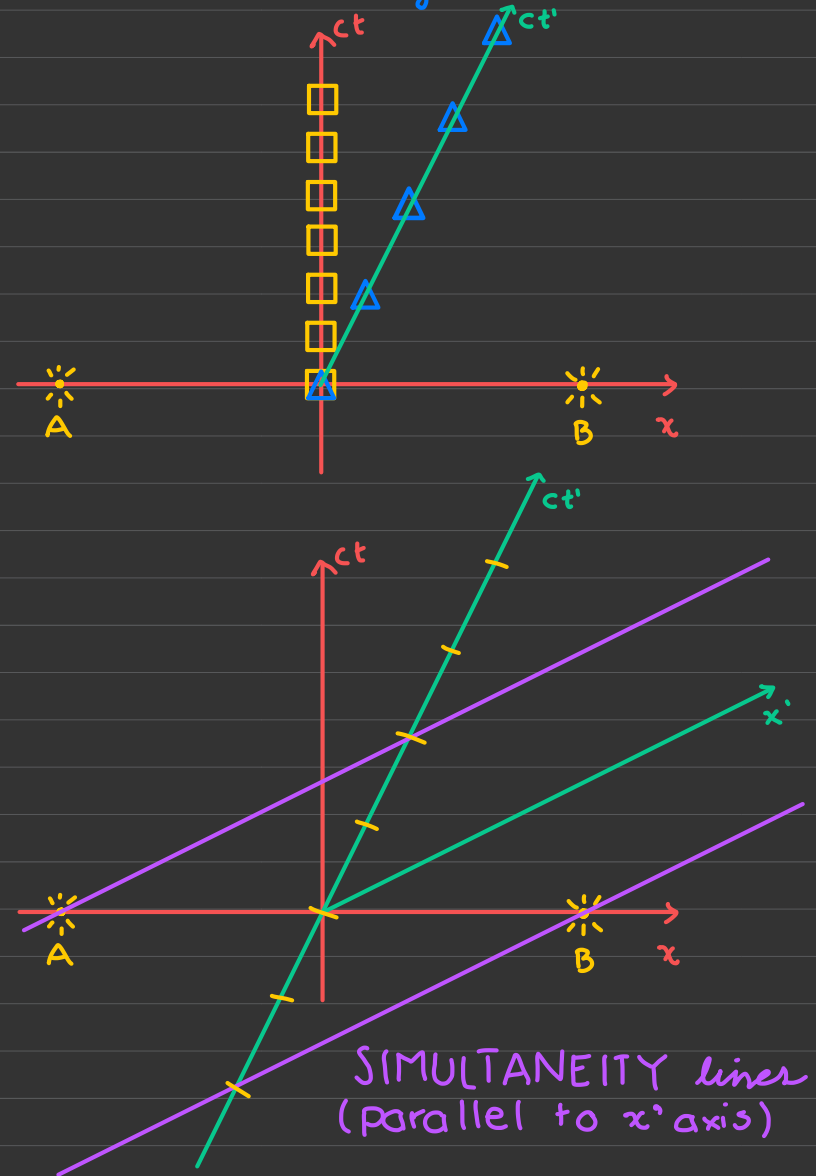
Q. Does the triangle see the two
lightnings **at the same** time as well?

Are the events **simultaneous** from the
triangle's frame of reference?

HINT: use a ST diagram!

SOLUTION

SPACETIME diagram ~



Notice that from the triangle's frame of
reference **B** happens **BEFORE** **A**

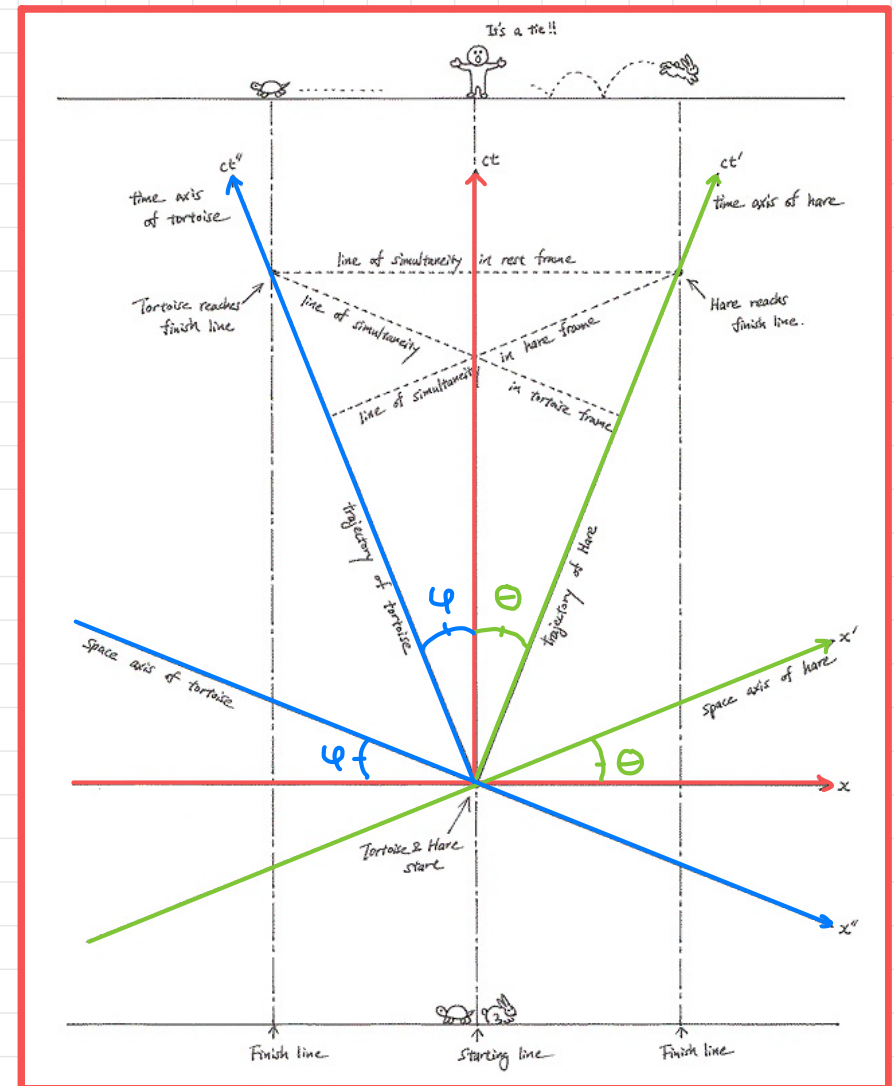
The Hare and the Tortoise

The hare and the tortoise decide to have a race. But instead of running in the same direction toward the finish line, they decide to run in opposite directions toward finish lines located at equal distances from the starting line as shown in the figure.

The race takes place and the referee sees both animals finish at the same time in the frame at rest with respect to the ground. Assuming that the two animals move at a constant velocity from start to finish, what is the result of the race as seen from the frames of the two moving animals?

Choose from one of the following and explain the reason for your choice. You are encouraged to draw a spacetime diagram to facilitate your explanation.

- Both the hare and the tortoise think that they won.
- Both the hare and the tortoise think that they lost.
- The hare thinks it won and the tortoise thinks it lost.
- The hare thinks it lost and the tortoise thinks it won.
- None of the above.

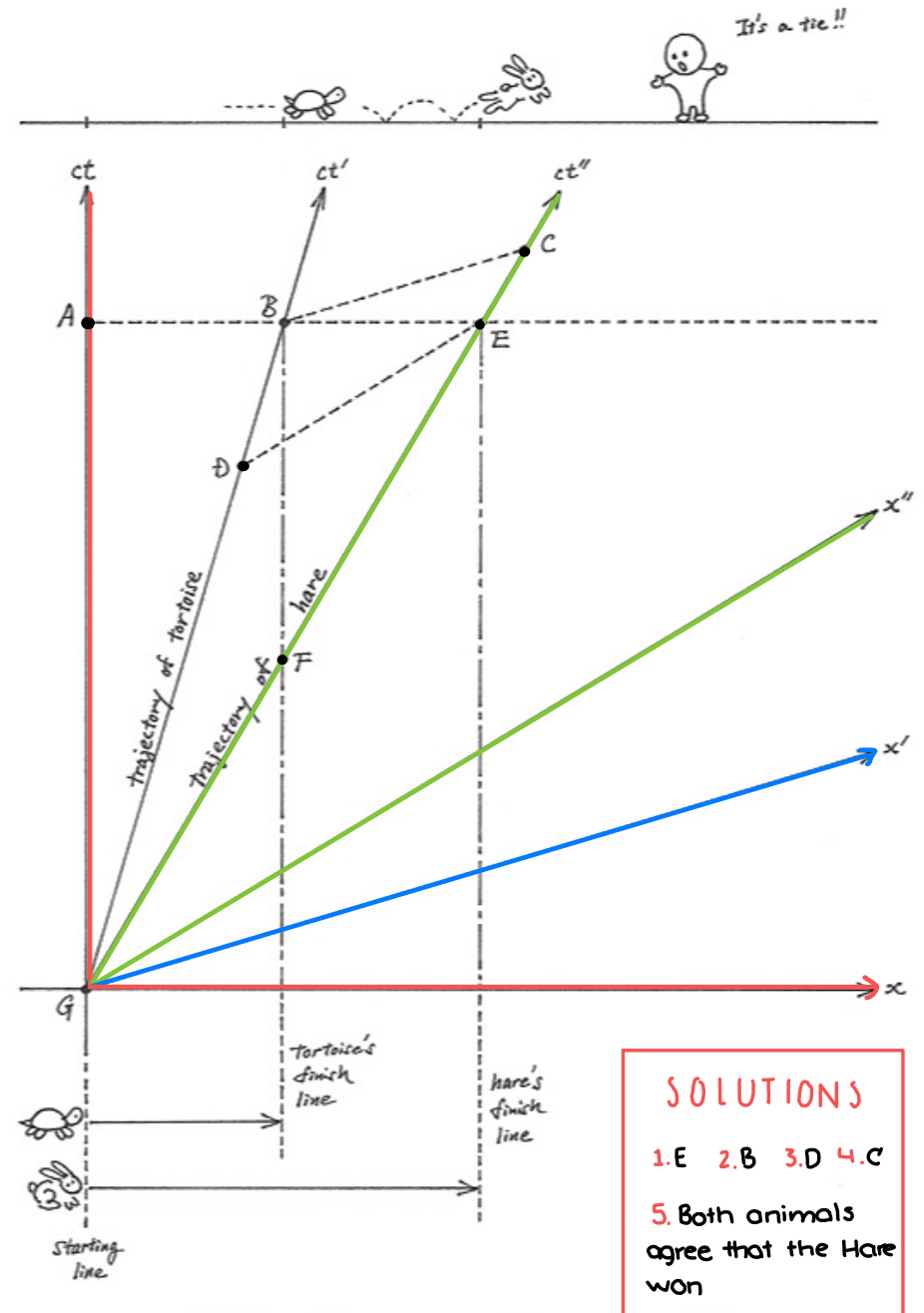


SOLUTION (a)

II

The hare and the tortoise decide to have another race. They start from the same point and race in the same direction, but the hare decides to give the tortoise a handicap by letting him race only half the distance as shown in the figure. The race takes place and the referee, who is at rest with respect to the ground, sees both animals cross their respective finish lines at the same time. The trajectory of the hare and the tortoise are shown on the space-time diagram. Answer the following questions:

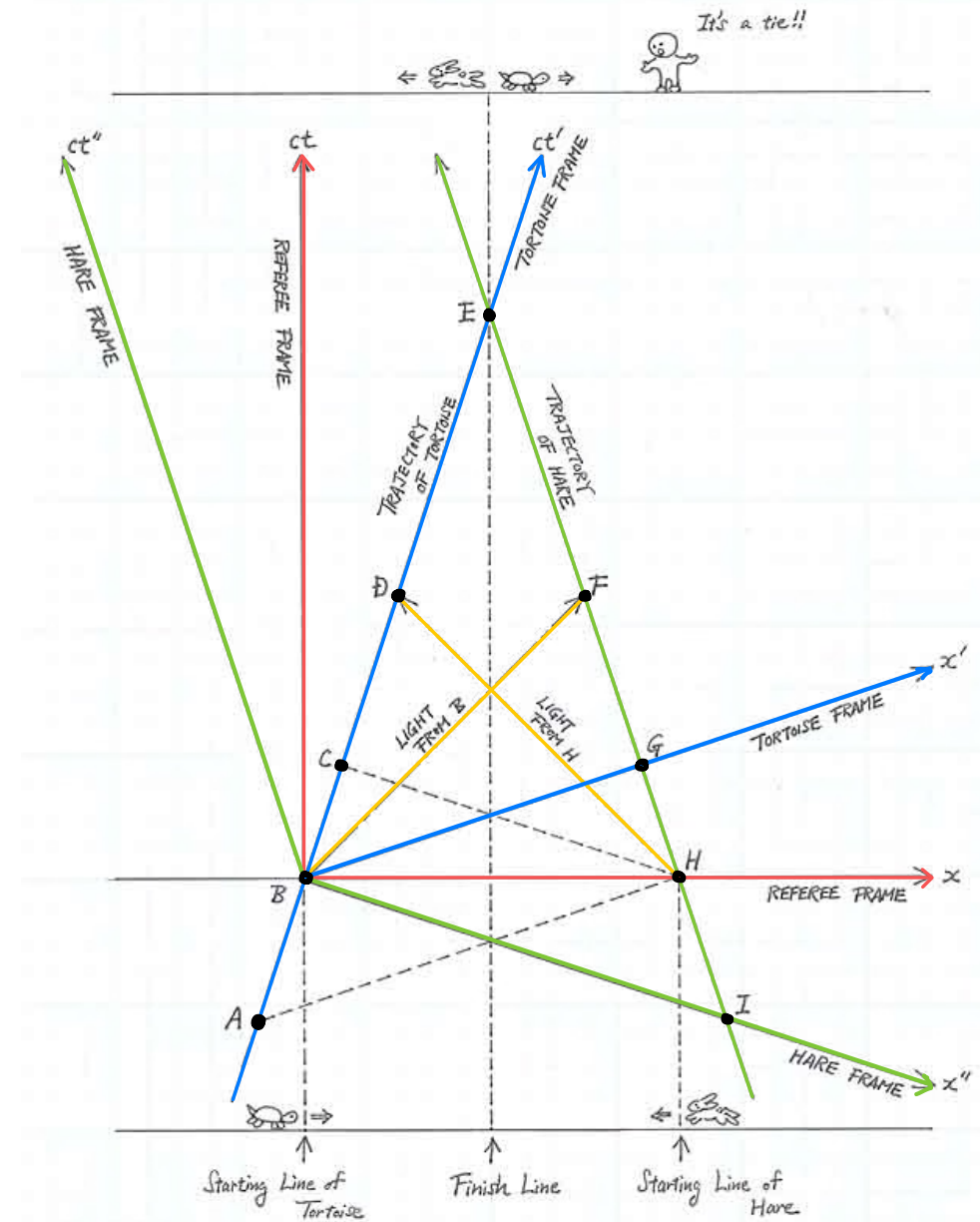
- 1) At which of the points labeled A through G in the space-time diagram does the hare cross its finish line?
- 2) At which point does the tortoise cross its finish line?
- 3) At which point is the tortoise when the hare crosses its finish line in the hare frame?
- 4) At which point is the hare when the tortoise crosses its finish line in the tortoise frame?
- 5) What is the result of the race in the respective frames of the hare and the tortoise? Do they agree or disagree? If they disagree, explain why it is not a contradiction.



III

In an act of pure competitiveness, the hare and the tortoise decide to have yet another race. This time, they start out from opposite directions the same distance away from the finish line, as shown in the figure, and race toward each other. In the frame of the referee, which is at rest relative to the ground, the two animals cross their respective starting lines *at the same time* and then cross the finish line *at the same time* from opposite directions. The referee declares the race a tie. Assume that both animals were moving at constant velocities before, during, and after the race. Answer the following questions:

- 1) In the frame of the tortoise, at which event is the hare *when* the tortoise crosses its starting line?
- 2) At which event does the hare *see* the tortoise start?
- 3) Do both animals agree with the referee that *they started at the same time*? If not, explain in what chronological order the animals start in each animal's frame.
- 4) Do both animals agree with the referee that *they finished at the same time*? If not, explain in what chronological order the animals start in each animal's frame.



SOLUTION: 1. G 2. F

3. No, they do not agree. The tortoise starts at B while the hare starts at H. In the tortoise frame, B is simultaneous with G which is chronologically later than H. In the hare frame, H is simultaneous with C which is chronologically later than B. So both animals will think that the other animal started earlier than they did. (The tortoise will not see the hare starting until it is at D, and the hare will not see the tortoise starting until it is at F. So if the animals do not take into account the finite time it takes for light to reach them from their opponent's starting points, they may reach the opposite conclusion.)
4. Yes, they will agree. Both animals cross the finish line at E.