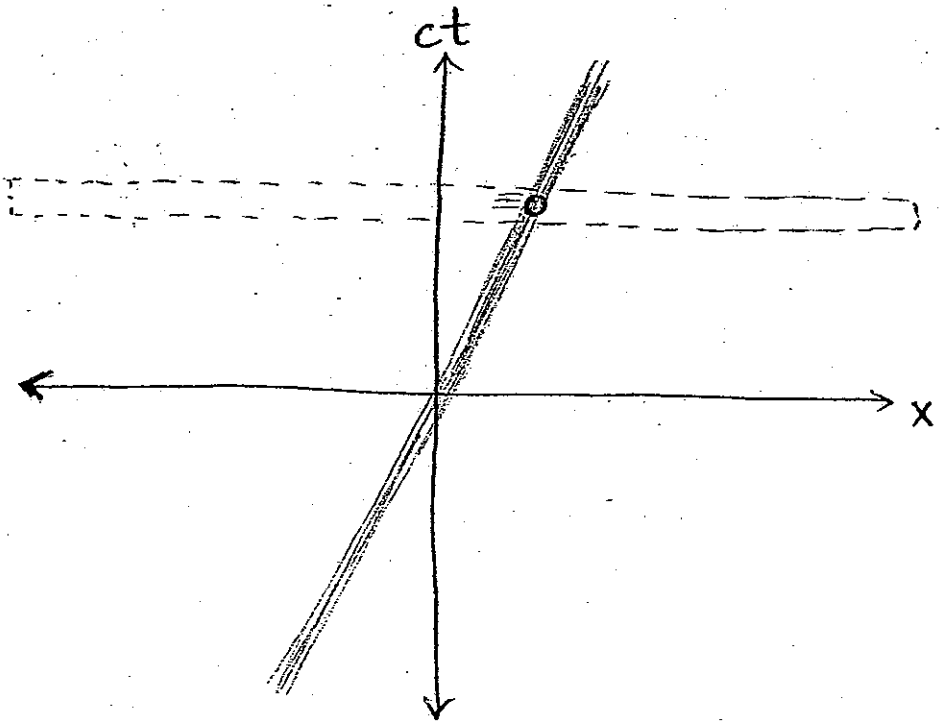
Physics 200 Tutorial 4:

Spacetime Diagrams

In this tutorial, you will get some practice using spacetime diagrams to visualize events and trajectories, and help resolve some of the apparent paradoxes of special relativity.

Things to remember:

- We will always be talking about events and trajectories happening only along one spatial direction, represented by the horizontal direction on the diagram.
- The vertical direction corresponds to time. Each horizontal slice represents a snapshot of what's happening at a particular time



spacetime diagram of a ball moving at positive x velocity

Question 1

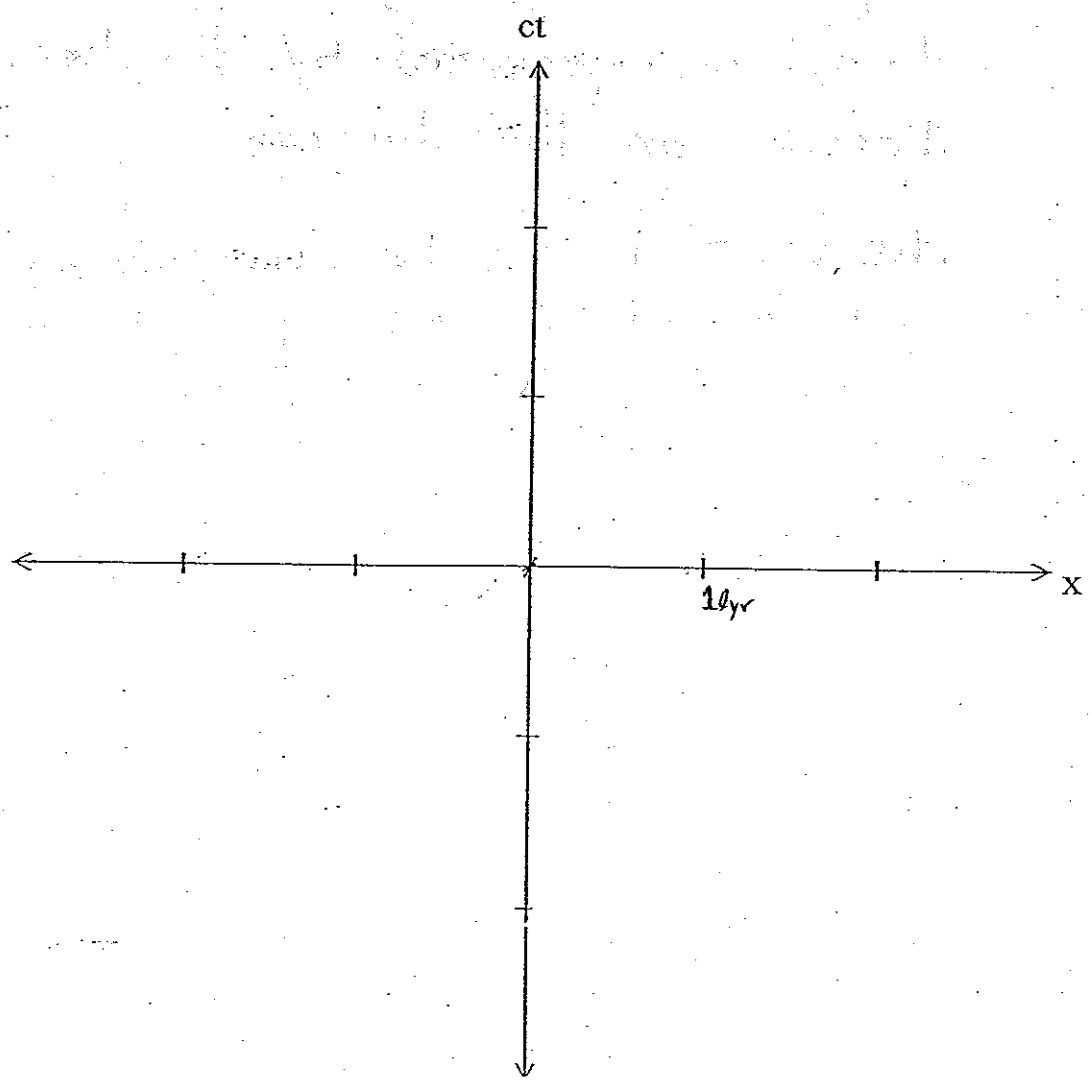
On the spacetime diagram below, draw

a) a stationary object at x= -2 lyr

b) a pulse of light travelling in the $+\hat{x}$ direction that is at x = -1 lyr at time t=0.

c) an object travelling at v = -0.5c that passes x=0 at time t = 2 years.

Indicate on the diagram the events where the light pulse passes the object in part a) (use a + to show this) and where the light pulse passes the object in part c (use a * to show this).



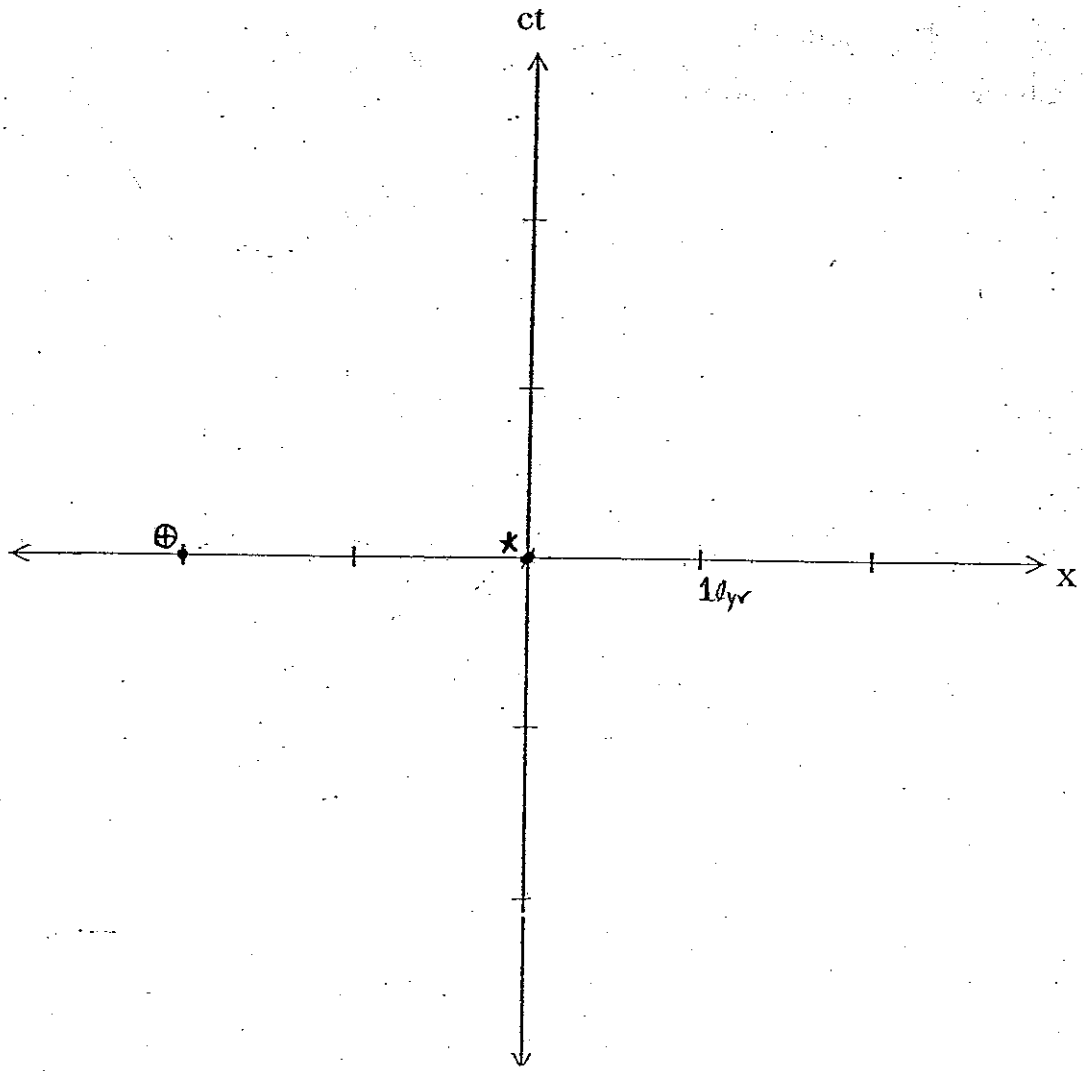
Question 2

On the spacetime diagram below, draw

a) an object travelling at v = 0.5c that passes x=0 at t=0 (indicate this with a solid line)

b) the set of events that are simultaneous in the frame of this object with the event marked by a * (use a dashed line)

c) The set of events that are measured to be at the same place in the objects frame as the event marked by a ⊕



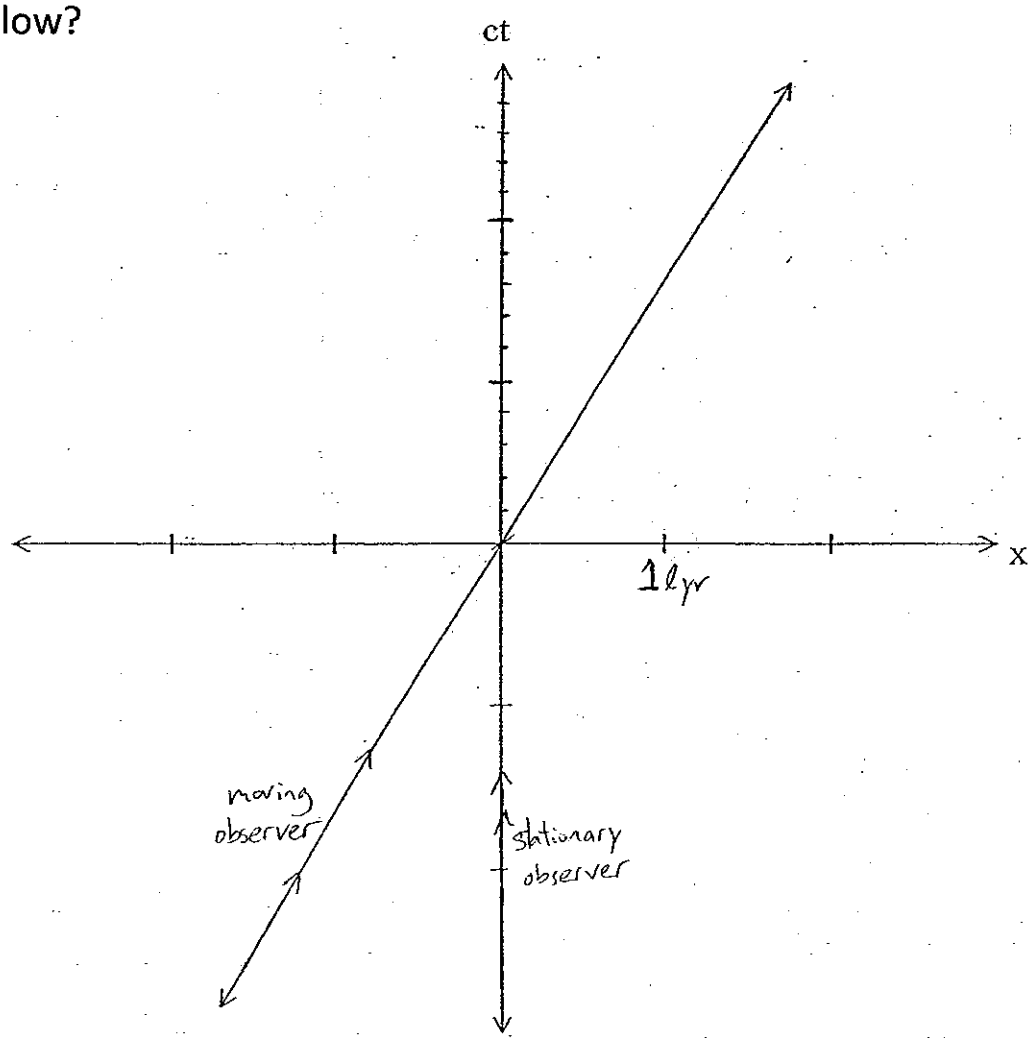
Question 3

The spacetime diagram below shows an observer moving at 0.6c in the $+\hat{x}$ direction, and a stationary observer at x=0. Assume that both set their clocks to zero when they pass.

a) Indicate on the diagram the events where the stationary observer's clock reads exactly 2 years (use a +) and where the moving observer's clock reads 2 years (use a *). Hint: what does time dilation tell you?

b) Indicate the set of events that the stationary observer thinks are simultaneous with +, and the set of events that the moving observer thinks are simultaneous with *.

Can you see from the diagram that each observer sees the other's clock to run slow?



Question 4

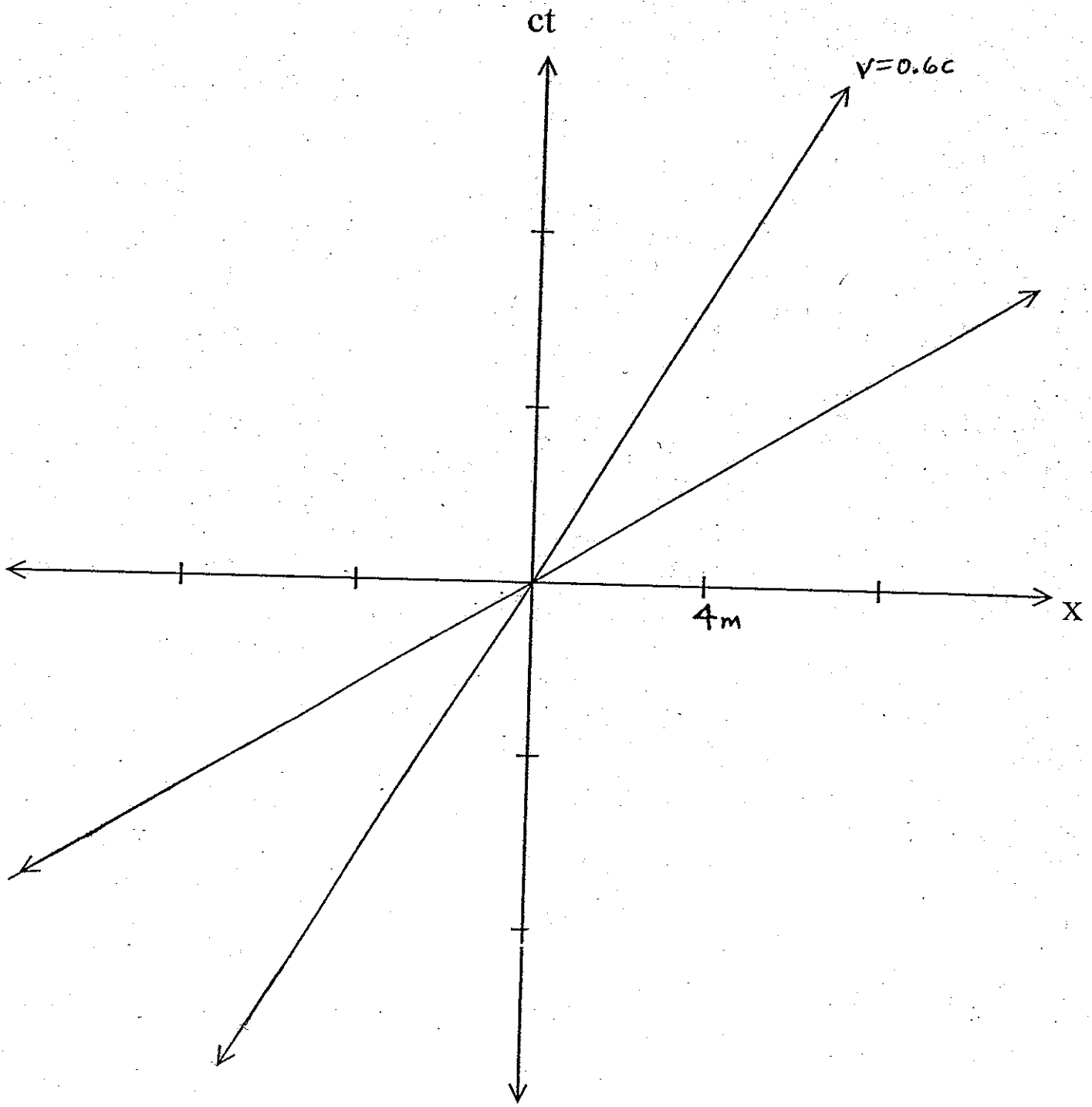
For Enid's 80th birthday, her husband Abraham decides to build a new 4 meter long garage for Enid's 4 meter long 1958 Edsel convertible. Unfortunately, the same day, Enid decides to give herself a birthday present and trades in her 4 meter long 1958 Edsel in for a 5 meter long 2009 Hummer. As she arrives back home, she sees the new garage, and not wanting to hurt Abraham's feelings, accelerates to $0.6c$. Since $\gamma = 5/4$ for $v = 0.6c$, she knows that Abraham will observe observe her vehicle to be only 4 meters long and therefore should see her Hummer (barely) fit in the garage he has made. Everything works out as planned, and Abraham closes the door of the garage just when he observes the front of the Hummer reach the far inside wall of the garage.

Now, you might ask, how can it be that the 5 meter long Hummer can fit in the 4 meter long garage? To resolve this apparent paradox, let's use a spacetime diagram.

a) On the attached spacetime diagram, assume that each tick represents 4 meters, and that the (x, t) coordinates correspond to the frame of the garage. Take the door of the garage to be at $x = 0$ and the far inside wall to be at $x = 4m$. Also, assume that the back of the Hummer is at $x' = 0$ and that this coincides with the door of the garage at $t = t' = 0$.

Draw (carefully!) the trajectories of the front and back of the garage and the Hummer on the spacetime diagram. Indicate with an star the event where the front end of the car reaches the far inside wall of the garage. Indicate with an 'A' the event where Abraham closes the door of the garage. Indicate with an 'E' the back end of the Hummer in Enid's frame when she observes the front end of the Hummer reaches the wall of the garage. Finally, indicate with a 'Z' where Enid observes the front of her car to be at the same time that she observes Abraham to close the door.

b) Based on your diagram, explain the resolution of the paradox.


ct
v=0.6c
x
4m