Think back to when you first learned Special Relativity. Your new relativistic universe is a modification to the universe of Newton because you have added three new principles to Newtonian physics: 1. Length Contraction 2. Time dilation 3. Failure of Simultaneity at a Distance. At first, these principles seem to be strange contradictions to everything Newton said, but ultimately they fit seamlessly into Newton's physics and solve some problems that Newtonian physics could not.

Having accepted that Special Relativity is the "next step" after Newtonian physics, what would be the next step after Special Relativity? General Relativity? No. There is no next step because Special Relativity has never been completed. The most glaring example of this is that length contraction has never been fully explained. If an object is subject to length contraction at a constant velocity, then how does this length contraction occur as the object accelerates to that velocity?

Consider the experiment where a short bar undergoes length contraction during acceleration. This is the simplest possible acceleration experiment, yet no explanation currently exists describing mathematically what happens to the length and time coordinates along this bar during the acceleration. Physicists casually state that this is not important, then report the results of General Relativity as it describes how gravitational acceleration modifies the three length dimensions of universal space. What? Relativity can describe the most complex dimensional problem imaginable, but can't describe the simplest? That's totally backwards. Current theory completely ignores the fact that the universe is made up of objects that have length to them and that these objects accelerate. And General Relativity cannot describe the short bar acceleration process.

If someone sets out to describe what happens during the simple bar acceleration experiment, how would he do it? Current relativity describes the movement of point objects, so a bar could be modeled as two point objects located at each end. With this assumption, all of the normal equations for point object movement in Special Relativity could be used to describe the mathematics of accelerating an object with length.

Basic Definitions

This process begins with the definition of some basic ideas. Consider Figure 1, where a bar is stationary in reference frame A. The velocity of frame A relative to stationary frame B is v. Observers in frame A measure the length of the bar to be L_A and observers in frame B measure the length of the bar to be L_B and:

$$L_B = L_A \sqrt{1 - \frac{v^2}{c^2}}$$

(1)

Special Relativity defines length as the distance between two points (or point objects). To be more precise, length is the difference in two simultaneous coordinate measurements of the location of those points along the reference frame axis.
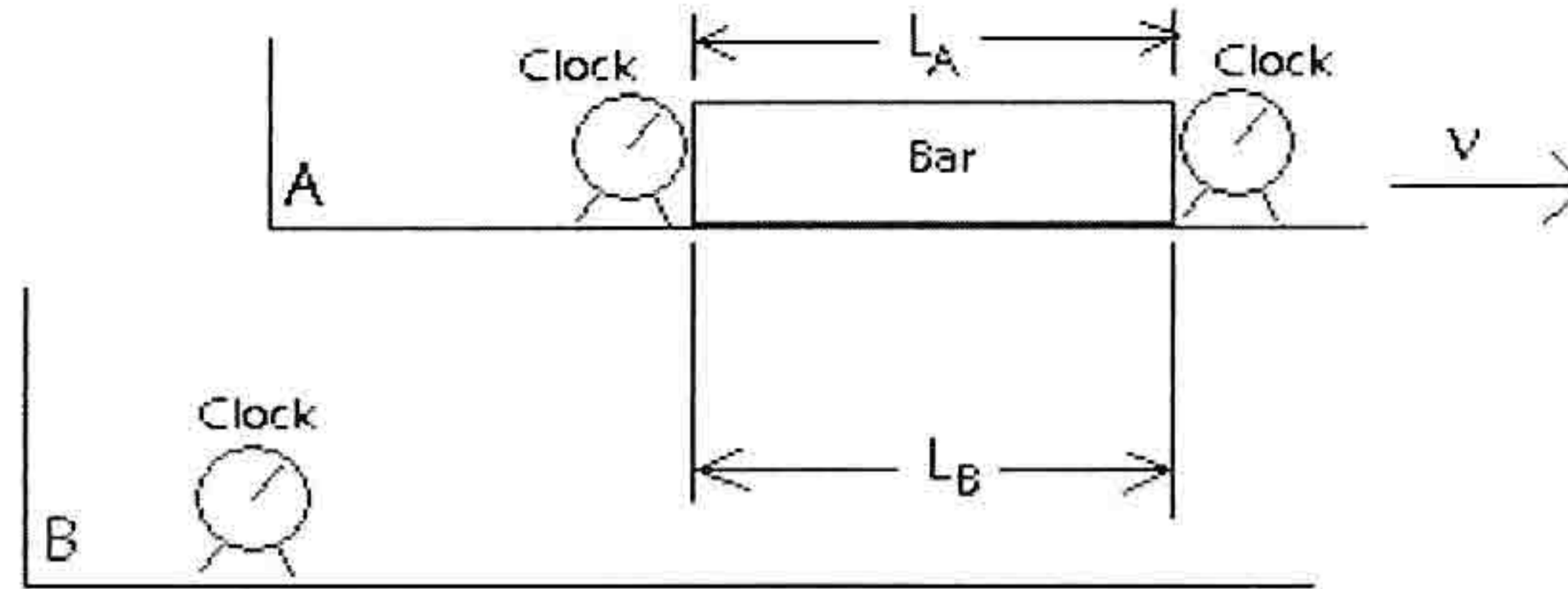
Figure 1. Defining length contraction, time dilation and simultaneity.

In (1), L_A or L_B is the distance between two coordinate points in reference frames A or B, and c is the velocity of light. Equation (1) is length contraction.

If clocks are located in frame A and frame B, the passage of time period t_A on frame A clocks will be seen by observers in frame B as a passage of time period t_B and:

$$t_A = t_B \sqrt{1 - \frac{v^2}{c^2}}$$

(2)

Equation (2) is time dilation. Frame B will also observe that the clock riding on the front of the bar reads less than the clock riding on the rear of the bar by Δt and:

$$\Delta t = -\frac{L_A v}{c^2}$$

(3)

Equation 3 is failure of simultaneity at a distance. Equations (1), (2) and (3) are all constant velocity equations.
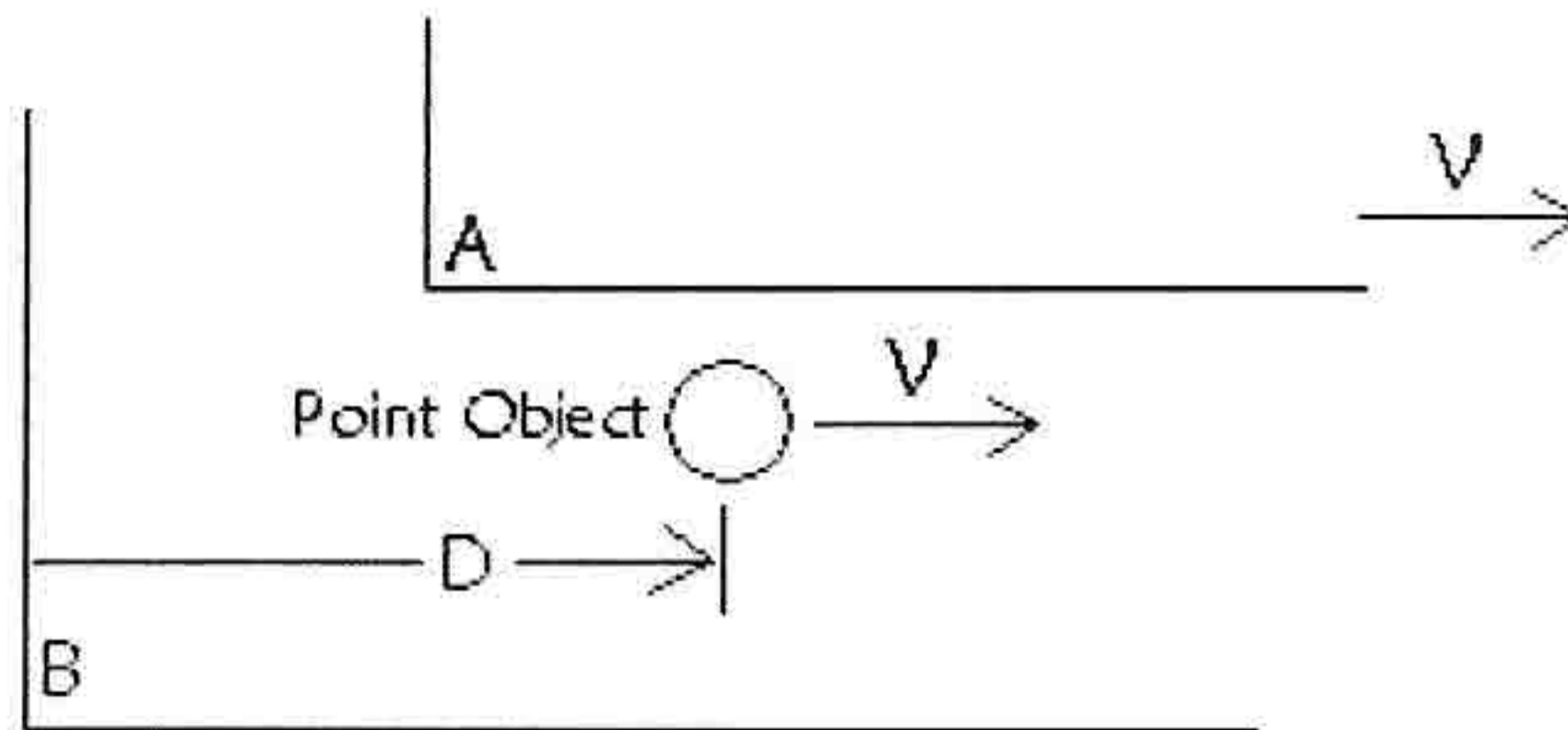
Simple Acceleration

Figure 2. A simple acceleration experiment.

In Figure 2, a point object (represented by the circular shape) starts the experiment at the origin of stationary frame B. The object accelerates up to velocity v where it becomes stationary in moving reference frame A. The acceleration process takes the object a distance D as measured by frame B. The goal of this discussion is to describe how length contraction occurs during acceleration. So, as a "first guess", a hypothesis is now offered.

> Hypothesis: An acceleration of an object with length can be modeled as the **_simultaneous_** and **_identical_** accelerations of two point objects at the ends of the object.

In Figure 3, two objects are shown accelerating just like the single object of Figure 2. These objects are a distance L_B apart before accelerating. Since the accelerations are identical, both object require distance D for the acceleration. Both objects start simultaneously and both achieve velocity v simultaneously (as seen by reference frame B). Therefore, frame B still must see the objects a distance L_B apart after the acceleration.
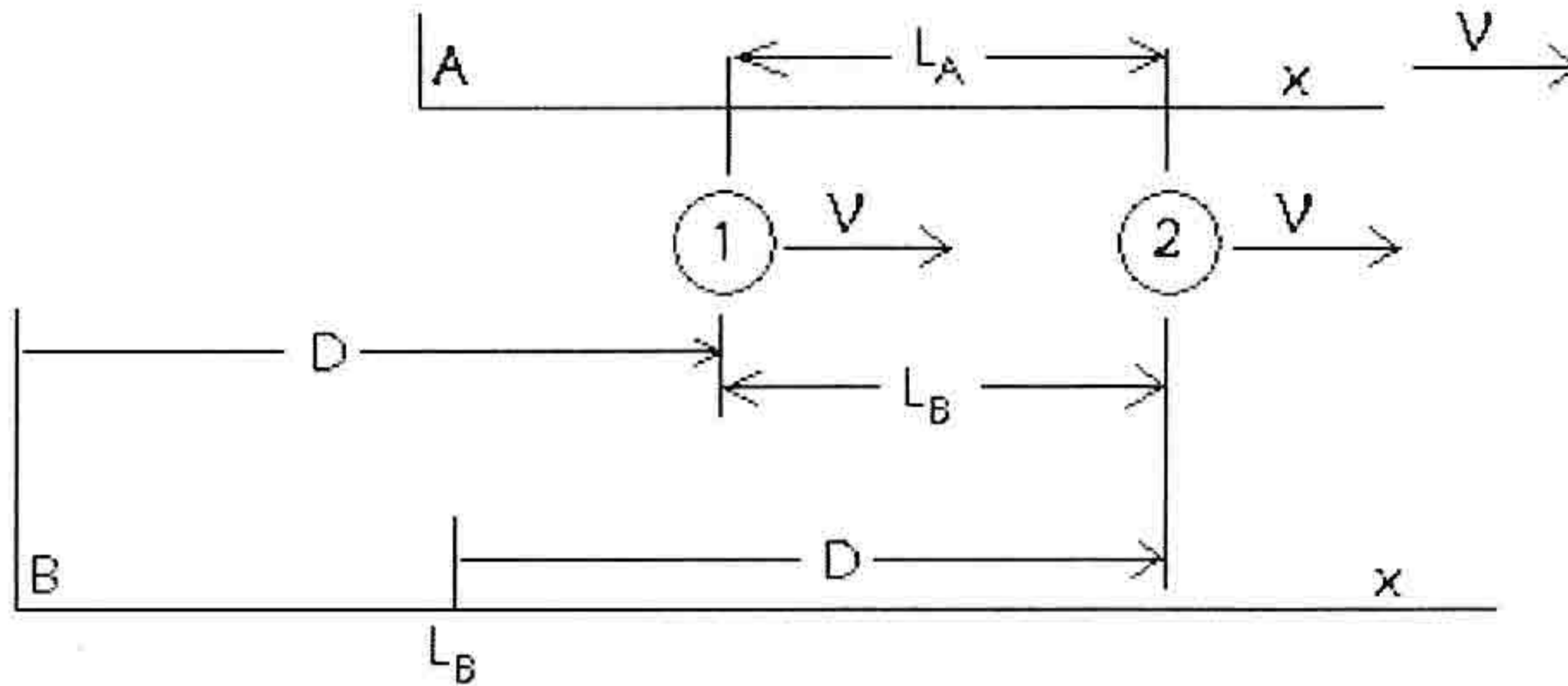

Figure 3. Accelerating two objects a distance L_B apart.

But, due to the length contraction of the moving frame A x-axis, frame A must see them a distance L_A apart and:

$$L_A = \frac{L_B}{\sqrt{1 - \frac{v^2}{c^2}}}$$

(4)

If a spring had connected the two objects when stationary in frame B, the spring would be stretched when the objects were stationary in frame A after the acceleration. The same thing would happen if two objects stationary in frame A were decelerated identically as seen by frame A, until they became stationary in frame B. See Figure 4.
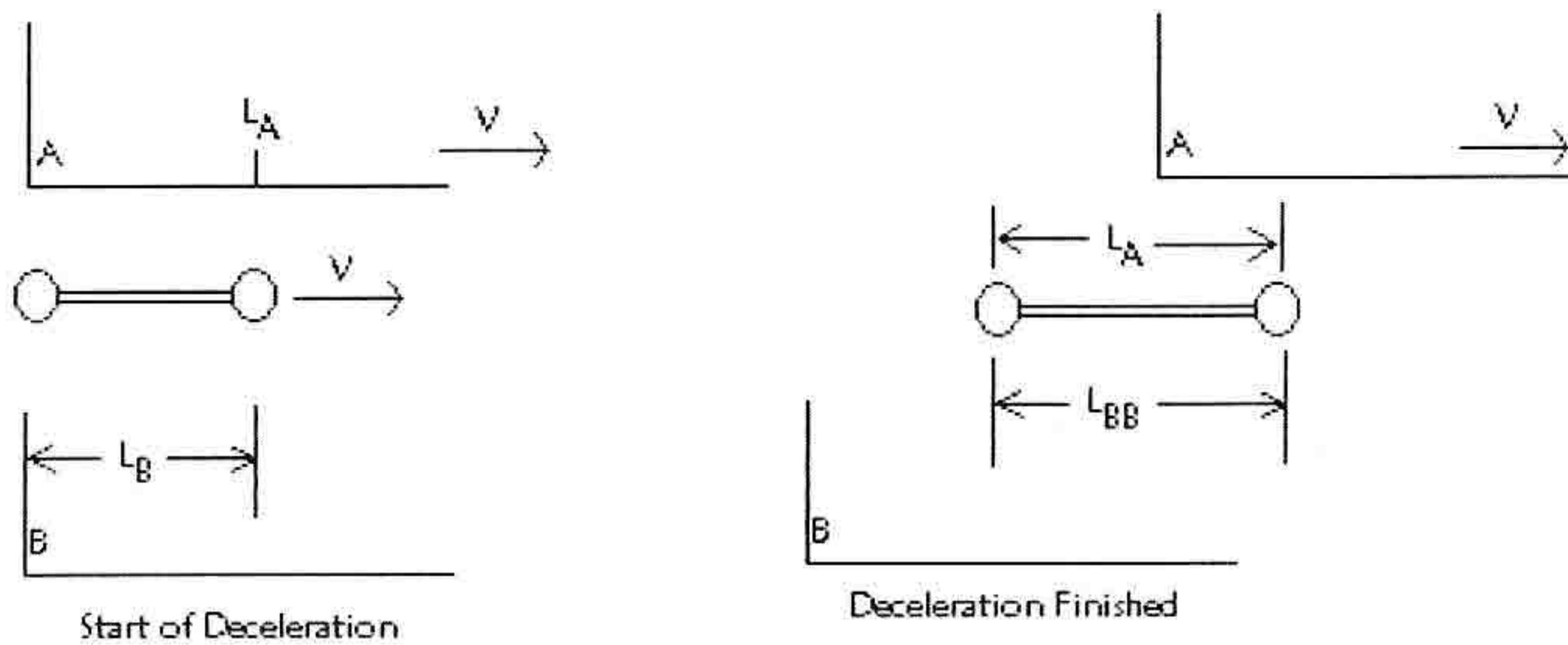
Figure 4. Frame A sees two objects decelerate identically to frame B.

The distance between the two objects is L_A when they are stationary in frame A. Frame B would see the spacing between them initially as (1). Since the objects start decelerating simultaneously in frame A, they do not start decelerating simultaneously in frame B due to (3). The rear object starts decelerating first. The separation between the objects seen by frame B (as they finish decelerating) is the initial separation plus the distance moved by the front object as it waits for its clock reading to be the same as the rear object (so the front object can start decelerating). Frame B does see the two objects decelerate identically over distances D.

$$Separation = L_B + \frac{\frac{L_A v}{c^2} v}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{5}$$

So they end up further apart in frame B as compared to frame A. The separation between the two objects when they come to rest in frame B would be L_{BB} and:

$$L_{BB} = \frac{L_A}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{6}$$

A spring connecting the two objects would have to stretch in this case too. Figure 5 shows the same two objects in frame A, but this time decelerated identically as seen by frame B. Equation (1) again describes the initial object spacing. If they decelerated identically, frame B would still see this same spacing when they became stationary in frame B. A spring placed between them would be compressed, not stretched.
The spring in these experiments becomes stretched or compressed based upon where it

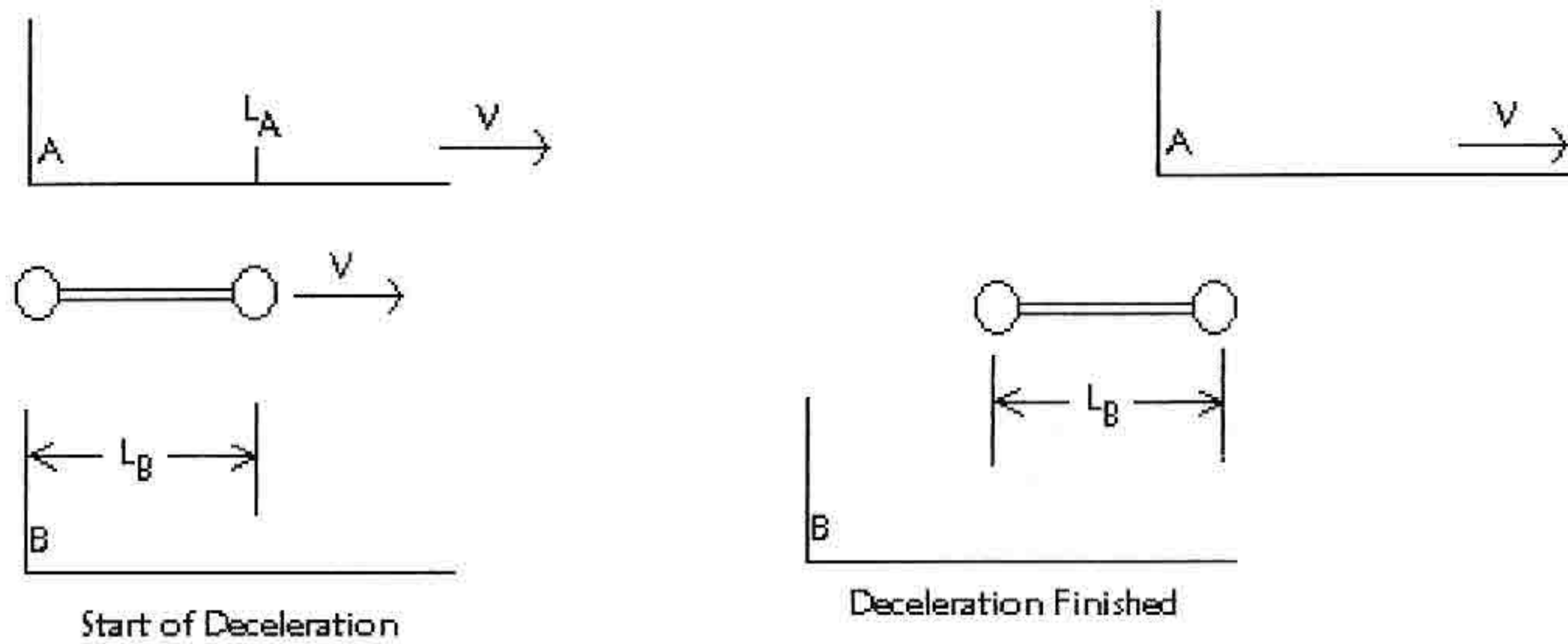starts and who sees the identical accelerations.

Figure 5. Frame B sees two objects decelerate identically to frame B.

Assuming that frame B supplies all the energy to accelerate or decelerate the objects, the total energy needed for the experiment of Figure 3 would be the sum of the individual kinetic energies needed to accelerate the two objects, KE_1 and KE_2, and the energy to stretch the spring SE.

$$Energy = -KE_1 - KE_2 - SE \qquad (7)$$

In the experiment of Figures 4 and 5, the total energy recovered by frame B would be:

$$Energy = KE_1 + KE_2 - SE \qquad (8)$$

Isn't it strange how complicated the analysis has gotten using the simple Hypothesis? A strange SE term has suddenly appeared. The energy needed to accelerated the object with length appears to include the energy to stretch or compress the object. This is not length contraction, this is real stretching or compressing of the object. Is this illogical? This situation has actually been identified in traditional Special Relativity with a familiar example called the Ladder Paradox.

The Ladder Paradox

The Ladder Paradox is familiar to most students of Special Relativity. A man runs into a garage carrying a ladder. See Figure 6. When at rest, the ladder is longer than the garage. But at speed, the ladder fits into the garage. Almost as an afterthought, it is mentioned at the end of the story that a friend shuts the garage door once the ladder is completely inside. The man stops running and the ladder crashes through the walls as it reverts to its original length. See Figure 7. Although there is a comical quality to the story, it is a

critical experiment in relativity. Relativity theory can advance no farther until this paradox is resolved.

The Law of Conservation of Energy

Does this experiment break the Law of Conservation of Energy? At the start, the man is stationary outside the garage. He begins running and expends some energy to get up to speed. When he gets into the garage, he slows back down and gets all of this energy back again. Shutting the door takes zero energy. When the ladder crashes through the walls, isn't this energy created by the experiment?
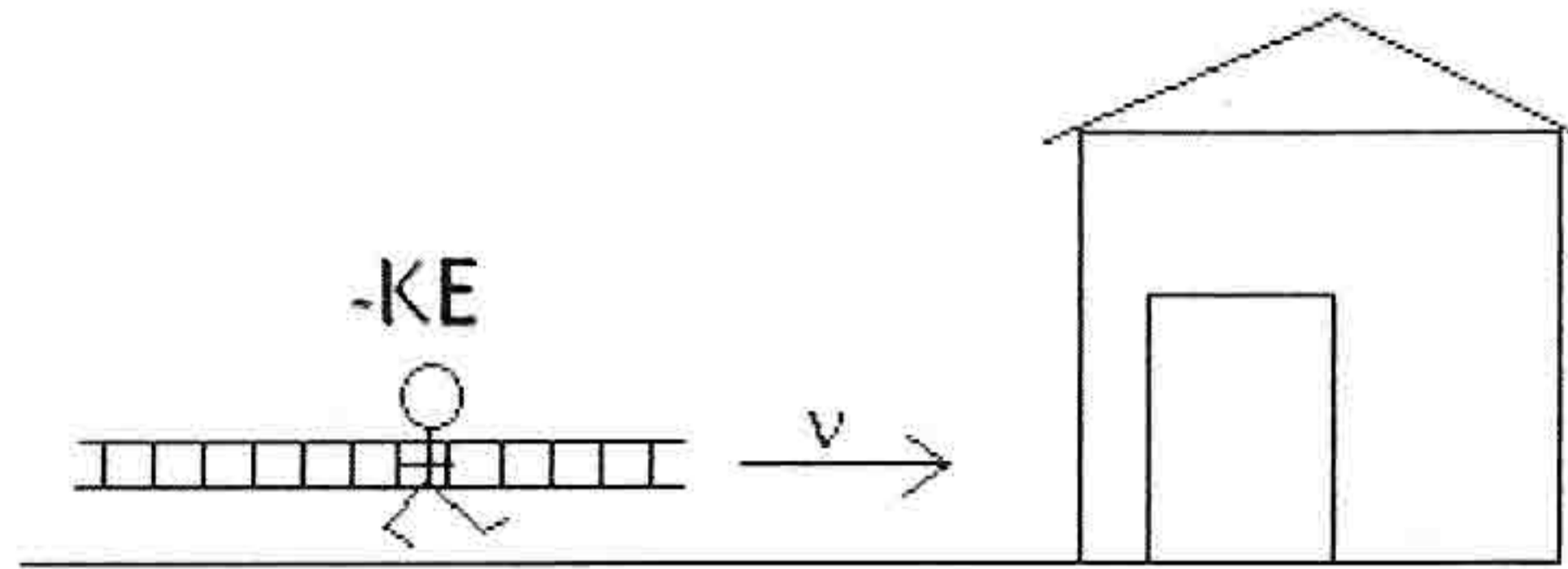

Figure 6. The man uses energy to get up to speed.

All of the energy used in this experiment could be accounted for with (7) and (8). Energy SE is the energy that crashes through the walls.
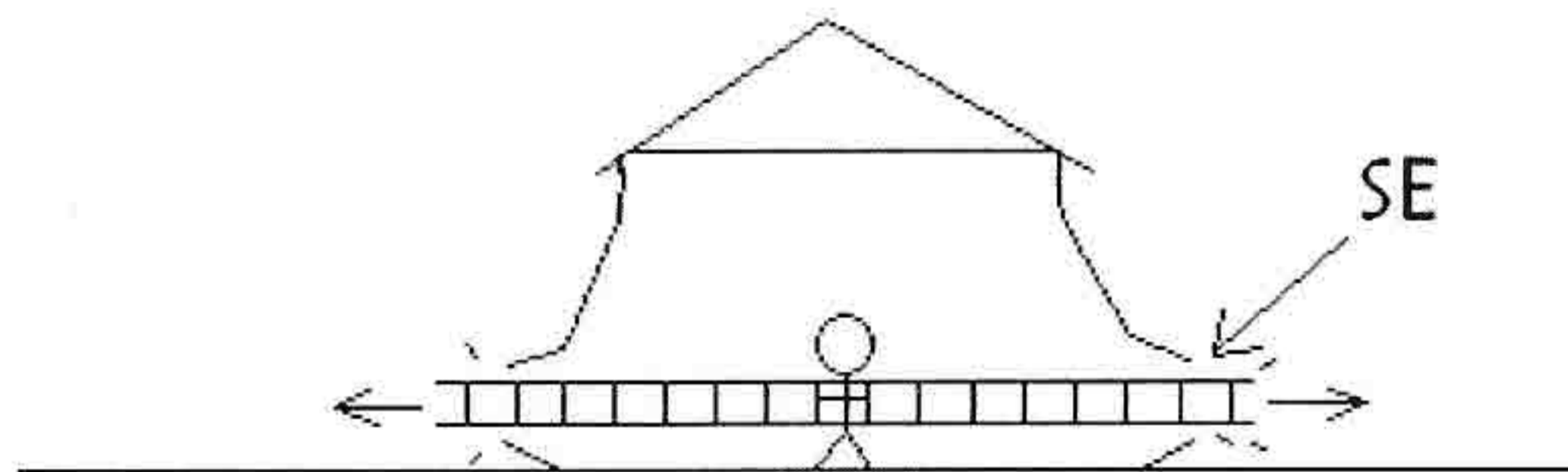

Figure 7. The man stops and the ladder crashes through the garage using energy SE.

Conclusion

Does Special Relativity really require stretching or compression of an object during acceleration, this stretching/compressing being a dimensional change in addition to length contraction? This appears to be an awkward and complicated way to model acceleration. The Law of Conservation of Energy must be checked for a simple calculation of length

contraction? The energy to accelerate an object is dependent upon the rigidity of the accelerated object? This energy never did appear in the original length contraction equations of Special Relativity and seems an unlikely component of any legitimate theory dealing with acceleration.

It must be concluded that it is not likely that objects are stretched and compressed as they go through accelerations and decelerations. Perhaps this is why Special Relativity has been incomplete for the last century. The most obvious attempt to describe acceleration of objects with length gives confusing results. The Hypothesis must be wrong. The most logical "first guess" is not correct.

A good way is needed to see what happens to the length of objects when they undergo acceleration (or deceleration), and a new model is needed to describe this process. This new model must get rid of any stretching or compressing of accelerating objects, but it must also account for the energy of the ladder as it crashes through the garage walls. See the article *The Acceleration Law*.