HW
SR-3

# Synchronization and causality

Name _____

## I. Train in a tunnel paradox

A train moves with constant velocity down a straight track that passes through a tunnel. When the train is at rest with respect to the tunnel, the train is exactly the same length as the tunnel. However, the train in this case is moving relative to the tunnel at nearly the speed of light.

The engineer on the train says: "The tunnel is Lorentz-contracted and is shorter than the train; therefore at no time can the train be wholly within the tunnel."

The keeper of the tunnel says: "The train is Lorentz-contracted and is shorter than the tunnel; therefore, there will be a time at which the train is wholly within the tunnel."

They are both infuriated by their failure to reach an agreement.

A. The engineer decides to settle the issue by placing rockets on the front and rear of the train, equipped with timing devices such that the rockets will be launched simultaneously, in a vertical direction, when the midpoint of the train passes the midpoint of the tunnel. (The engineer synchronizes these timing devices while the train is approaching the tunnel.)

1. Describe the relevant events in words. Include what happens, where it happens, and when it happens in each event description.

2. Make event diagrams for the train frame and the tunnel frame, showing the train and the tunnel at the instant associated with each event. Your pictures should show the qualitatively correct relative lengths of objects and relative times of events.

Event diagram for train frame

Event diagram for tunnel frame

© *Tutorials in Introductory Physics*, L.C. McDermott, P.S. Shaffer, and the Physics Education Group, University of Washington, Seattle, Spring 1999.

3. Is there any physical damage to the train and/or the tunnel as a result of the engineer's action:

   - in the train frame?
   - in the tunnel frame?

   Use your pictures to support your answers.

B. The tunnel keeper then tries to settle the issue (permanently) by erecting giant iron gates at the front and rear of the tunnel, equipped with timing devices such that the gates will close simultaneously when the midpoint of the train passes the midpoint of the tunnel. (The tunnel keeper knows that this will destroy the train and perhaps the tunnel when the front end of the train plows into a gate, but is so infuriated as to not care.)

1. Describe the relevant events in words. Include what happens, where it happens, and when it happens in each event description.

2. Make event diagrams for the train frame and the tunnel frame, showing the train and the tunnel at the instant associated with each event.

Event diagram for train frame

Event diagram for tunnel frame

© *Tutorials in Introductory Physics,* L.C. McDermott, P.S. Shaffer, and the Physics Education Group, University of Washington, Seattle, Spring 1999.

3. Is there any physical damage to the train and/or the tunnel as a result of the tunnel keeper's action:

   - in the rain frame?
   - in the tunnel frame?

   Use your pictures to support your answers.

© *Tutorials in Introductory Physics,* L.C. McDermott, P.S. Shaffer, and the Physics Education Group, University of Washington, Seattle, Spring 1999.