

## Exam #1

### 1) Cosmic Speedometer

(4 points)

If you see a person traveling through space at half the speed of light, you will also see his clocks running:

- a) at half their normal speed
- b) slower than half their normal speed
- c) slower, but not slowed to half speed
- d) at normal speed
- e) backwards

### 2) High-speed spear

(4 points)

A spear 10m long is thrown at a relativistic speed through a pipe that is 10 m long. Both these dimensions are measured when each is at rest. When the spear passes through the pipe, which of the following statements best describes what is observed?

- a) The spear shrinks so that the pipe completely covers it at some point
- b) the pipe shrinks so that the spear extends from both ends at some point
- c) both shrink equally so the pipe just covers the spear at some point
- d) any of these, depending on the motion of the observer

### 3) Invariants

(8 points)

Which of the following are invariant (ie: agreed on by all inertial observers)?

- a) time ordering of time-like separated events
- c) component of the velocity of a projectile parallel to relative direction of motion
- b) component of the velocity of a projectile perpendicular to relative direction of motion
- c) time between events
- d) distance between events
- e) total particle speed when  $\beta < 1$
- f) total particle speed when  $\beta = 1$
- g) proper time along a world line

#### 4) Relative velocities

(12 points)

A rocket ship moving at  $0.5c$  wrt earth fires a missile which moves at  $0.8c$  wrt the rocket. What is the speed of the missile wrt earth, assuming classical physics (Galilean transformations)? What is the speed of the missile wrt earth, assuming relativity (Lorentz transformations)?

#### 5) Causality

(12 points)

You are located at the origin of the S frame:  $(x,t)=(0,0)$ . Your friend is located at the origin of the S' which is moving to the right at  $\beta = 0.99$  wrt the S frame in the usual way with origins coinciding at  $(0,0)$ . Consider the following space-time events (coordinates in S):

	(x,	t)
A =	(0 ,	2)
B =	(2.01,	2)
C =	(1.99,	2)
D =	(2,	0)
E =	(0,	-2)
F =	(2,	-1.99)
G =	(2,	-2.01)

- a) Which events can you causally effect ?
- b) Which events can your friend causally effect ?
- c) Which events can casually effect you?
- d) Which events can casually effected your friend?

**6) Olsen twins**

*(15 points)*

Mary-Kate and Ashley are famous child twin actors. They decide to try to prolong their combined effective career by sending one of them on a high-speed round-trip journey. Mary-Kate travels at speed  $\beta = 24/25$  away from earth for 7 years as measured by her. She then turns around and returns to earth with speed  $\beta = 24/25$ .

- a) How much older is Mary-Kate when she returns ?
- b) How much older is Ashley when Mary-Kate returns ?

**7) Analyze the Michelson and Morely experiment in the fixed star frame.**

*(20 points)*

Show that the null effect ( $\Delta t = 0$ ) can be accounted for with Relativity.

**8) Space-time diagrams***(15 points)*

Frames S and S' are moving relative to each other along the x axis. In frame S, Event A occurs at  $x_A = 0.5m$  and  $t_A = 0.5m$  and Event B occurs at  $x_B = -2.0m$  and  $t_B = -0.5m$ . The events are simultaneous in the S' frame.

- Mark the location of these events in the diagram below
- Draw axis for the S' frame
- From the diagram estimate  $\beta$ , the magnitude and direction of the speed of S' relative to S.
- Show where the two events occur in S'.  
(ie: mark the on the  $x'$  and  $t'$  axis the projected coordinates of A and B).

