

Due Friday, 19 May 2000

**0. PRACTICE** (You do not need to turn these in.)

- (a) Problem 12.7 on p. 488 of Griffiths.
- (b) Problem 12.8 on p. 489 of Griffiths.
- (c) Problem 12.9 on p. 493 of Griffiths.
- (d) Problem 12.13 on p. 498 of Griffiths.

**1. THE GETAWAY**

The outlaws are escaping in their getaway car, which goes  $\frac{3}{4}c$ , chased by the police, moving at only  $\frac{1}{2}c$ . Realizing they can't catch up, the police attempt to shoot out the tires of the getaway car. Their guns have a muzzle velocity (speed of the bullets relative to the gun) of  $\frac{1}{3}c$ .

- (a) Does the bullet reach its target according to Galileo?
- (b) Does the bullet reach its target according to Einstein?
- (c) Verify that your answer to part (b) is the same in all four (!) reference frames: ground, police, outlaws, and bullet.

*This is a combination of Problems 12.4 and 12.15 on p. 483 and p. 498 of Griffiths, respectively. You may answer part (c) using the table on p. 498.*

**2. ANGLES ARE NOT INVARIANT**

- (a) The mast of a sailboat leans at an angle  $\theta$  (measured from the deck) towards the rear of the boat. An observer on the dock sees the boat go by at speed  $v \ll c$  (so that you do **not** need to use relativity to do this problem). What angle does the observer say the mast makes?
- (b) A child on the boat throws a ball into the air at the same angle  $\theta$ . What angle does the observer on the dock say the ball makes with the deck?

*Ignore the subsequent influence of gravity on the ball — this question is only about the initial angle when the ball leaves the child's hand. You may wish to first consider the following special case: Suppose that the horizontal component of the ball's velocity exactly cancels the forward motion of the boat. What angle does the observer see?*

- (c) A spaceship goes past the dock at speed  $V$ . An antenna is mounted on the hull at an angle  $\theta$  with the (horizontal) hull. What angle does the observer on the dock say the antenna makes?
- (d) A spotlight is mounted on the spaceship so that its beam makes an angle  $\theta$  with the hull. What angle does the observer on the dock say the beam makes with the hull?
- (e) Briefly discuss the differences (if any) between your answers to these questions.

*This problem is based on Problems 12.10 and 12.14 on p. 493 and p. 498 of Griffiths, respectively.*

(CONTINUED ON BACK)

### 3. THE TWIN PARADOX I

Do Problem 12.16 on p. 499 of Griffiths.

*Be especially careful to note that the origins of all three coordinate systems are at the point of departure, **not** at the turnaround point.*

### 4. THE TWIN PARADOX II

*Consider the same scenario as in the previous problem.*

- (a) Draw a single spacetime diagram showing the entire trip in the reference frame of the stay-at-home twin. Your diagram should show the world lines of both twins.
- (b) The traveling twin's path consists of 2 segments: 1 outbound, and 1 inbound. Determine the "squared length" (interval) of each segment.
- (c) Draw in the lines of constant  $t$ ,  $t'$ , and  $t''$  which pass through the event of the traveling twin turning around. These lines divide the world line of the stay-at-home twin into 4 segments. Determine the "squared length" (interval) of each segment.
- (d) Compare the intervals just computed with the clock readings computed for the previous problem. Can you deduce a statement analogous to:

*The shortest distance between 2 points is a straight line*

which applies here?