

# Physics 322 Problem Set #1 (Introductory Special Relativity)

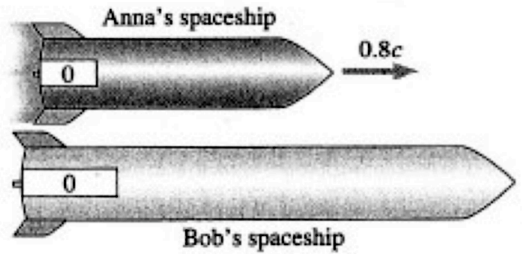
Due Friday, January 23 at 4:00 pm

**ASSUMED READING:** Before starting this homework, you should read Chapter 1 and Chapter 2.1 through 2.5 of Harris' *Modern Physics*.

**HINT:** None of these problems involve extended algebra (except possibly question 8). If you are doing a page of algebra, you may be on the wrong track.

1. **[Harris 2.1 modified]** Explain to your friend, who is will to accept that light moves at the same speed in any frame, why clocks on a passing train, which have been synchronized by having Anna stand in the middle of the train and observe clocks on the two ends of the train, are not synchronized in the frame of the ground. **Hint:** Bob will see the signals reach a *moving* Anna simultaneously... what does that mean?
2. **[Harris 2.3]** The Lorentz transformation equations have  $x$  and  $t$  and  $x'$  and  $t'$ . Why no  $v$  and  $v'$ ?
3. **[Harris 2.4 modified]** You are gliding over Earth's surface at high speed, carrying your high-precision clock. At points  $X$  and  $Y$  on the ground are similar clocks, synchronized in the ground frame of reference. As you pass over clock  $X$ , it and your clock both read zero (0).
  - a. According to you, do clocks  $X$  and  $Y$  advance slower or faster than yours?
  - b. According to the folks on the ground, does your clock advance slower or faster than theirs?
  - c. When you pass over clock  $Y$ , does it read the same time, an earlier time, or a later time than yours? (Make sure your answer agrees with what the ground observer would see)
  - d. Reconcile any seeming contradictions between your answers to parts (a) and (c).
4. **[Harris 2.22 modified]** According to Bob on Earth, Planet Y (uninhabited) is 5 ly away. Anna is in a spaceship moving away from Earth at  $0.8c$ . She is bound for Planet Y to study its geology. Unfortunately, Planet Y explodes. Bob sees the explosion 7 years after Anna left Earth, so knowing Planet Y is 5 ly away, works out the time of the explosion to be 2 years after Anna passed Earth. Call the passing of Anna and Bob time zero for both.
  - a. According to Anna, how far away is Planet Y when it explodes?
  - b. At what time does it explode?
  - c. What do these results mean? In other words, explain what is actually going on here.

5. **[Harris 2.25]** Anna and Bob are in identical spaceships, each 100 m long. The diagram shows Bob's view as Anna's ship passes at  $0.8c$ . Just as the backs of the ships pass one another, both clocks read 0. At the instant shown, Bob Jr., on board Bob's ship, is aligned with the front of Anna's ship. He peers through a window in Anna's ship and looks at the clock.



- a. In relation to his own ship, where is Bob Jr.?
  - b. What does the clock he sees read?
6. **[Harris 2.33]** A famous experiment detected 527 muons per hour at the top of Mt. Washington, New Hampshire, elevation 1910m. At sea level, the same equipment detected 395 muons per hour. A discriminator selected for muons whose speed was between  $0.9950c$  and  $0.9954c$ . Given that the mean lifetime  $\tau$  of a muon in a frame in which it is at rest is  $2.2\mu\text{s}$  and that in this frame the number of muons decays exponentially with time according to  $N = N_0 e^{-t/\tau}$ , show that the results obtained in this experiment are sensible.
7. **[Harris 2.45 tweaked]** Planet W is 12 ly from Earth. Initially, Anna and Bob are both 20 yr old and on Earth. Anna travels to Planet W at  $0.6c$ , quickly turns around, and returns to Earth at  $0.6c$ . How old will Anna and Bob be when Anna gets back?
8. **[Harris 2.53 modified]** At rest, a light source emits 532 nm light.
- a. As it moves along the line connecting it and Earth, observers on Earth see 412 nm. What is the source's velocity (magnitude and direction)?
  - b. Were it to move in the opposite direction at the same speed, what wavelength would be seen?
  - c. Were it to circle Earth at the same speed, what wavelength would be seen?
  - d. One (incorrect) model we give introductory students for Doppler Shift is that the waves get "crunched up" or "stretched out" between the source and the observer moving relative to each other, thus causing a change in wavelength. If an object is circling the Earth, you might expect it to exhibit no Doppler Shift, since it is neither moving towards or away from us. Why did you see a Doppler shift in part (c) [and now you know you should have!]? **HINT:** "Time dilation" is the answer, the hard part is grasping why!