

## Section thirteen Relativity

### Part One

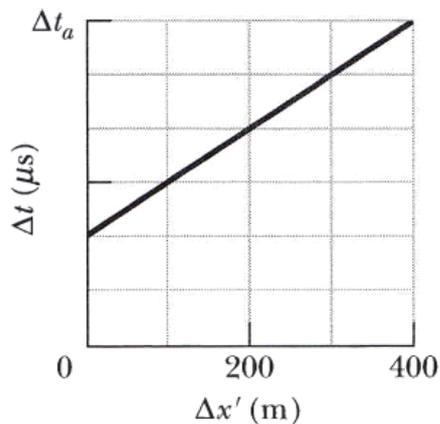
You've been named captain of NASA's first interstellar mission since the Voyager robotic spacecraft. You board your spaceship, accelerate quickly to  $0.8c$ , and cruise at constant speed toward Proxima Centauri, the closest star to our Sun. Proxima Centauri is 4 light-years distant as measured in the two stars' common rest frame. On the way, you conduct various medical experiments to determine the effects of a long space voyage on the human body.

1. Taking your pulse, you find
  - a. it's significantly slower than when you're on Earth.
  - b. it's the same as when you're on Earth.
  - c. it's significantly faster than when you're on Earth.
2. How much do you age during your interstellar journey?
  - a. 3 years
  - b. just under 4 years
  - c. just over 4 years
  - d. 5 years
3. Back on Earth, Mission Control judges that your shipboard clocks run slow. What do you judge about clocks at Mission Control?
  - a. They run fast.
  - b. They keep time at the same rate as your clocks.
  - c. They run slow.
  - d. You can't tell anything about their clocks.
4. In your spaceship's reference frame, the distance from the Sun to Proxima Centauri is
  - a. 2.4 light years.
  - b. just under 4 light years.
  - c. 4 light years.
  - d. 5 light years.

### Part Two

1 Earth and Sun are 8.3 light minutes apart, as measured in their rest frame. (a) What's the speed of a spacecraft that makes the trip in 5.0 min according to its on-board clocks? (b) What's the trip time as measured by clocks in the Earth–Sun reference frame?

2 As in Fig. 13.1, reference frame  $S'$  passes reference frame  $S$  with a certain velocity. Events 1 and 2 are to have a certain temporal separation  $\Delta t'$ , according to the  $S'$  observer. However, their spatial separation  $\Delta x'$  according to that observer has not been set yet. Figure 13.1 gives their temporal separation  $\Delta t$  according to the  $S$  observer as a function of  $\Delta x'$  for a range of  $\Delta x'$  values. The vertical axis scale is set by  $\Delta t_s = 6.00 \mu\text{s}$ . What is  $\Delta t'$ ?



3 Observer  $S$  detects two flashes of light. A big flash occurs at  $x_1 = 1200 \text{ m}$  and,  $5.00 \mu\text{s}$  later, a small flash occurs at  $x_2 = 480 \text{ m}$ . As detected by observer  $S'$ , the two flashes occur at a single coordinate  $x'$ . (a) What is the speed parameter of  $S'$ , and (b) is  $S'$  moving in the positive or negative direction of the  $x$  axis? To  $S'$ , (c.) which flash occurs first and (d) what is the time interval between the flashes?

4 Find the speed of a particle whose relativistic kinetic energy is 50% greater than the Newtonian value calculated for the same speed.