1. A starship blasts past the earth at $2.0 \times 10^8$ m/s. Just after passing the earth, the starship fires a laser beam out its back of the starship. With what speed does the laser beam approach the earth?

2. A cosmic ray travels 60 km through the earth's atmosphere in 430 $\mu$s, as measured by experimenters on the ground. How long does the journey take according to the cosmic ray?

3. An astronaut travels to a star system 4.5 ly (lightyear=distance light travels in a year) away at a speed of 0.9c. Assume that the time needed to accelerate and decelerate is negligible.
   (a) How long does the journey take according to Mission Control on earth?
   (b) How long does the journey take according to the astronaut?
   (c) How much time elapses between the launch and the arrival of the first radio message from the astronaut saying that she has arrived?

4. A starship voyages to a distant planet 10 ly away. The explorers stay 2.0 yr, return at the same speed, and arrive back on earth 26 yr after they left. Assume that the time needed to accelerate and decelerate is negligible.
   (a) What is the speed of the starship?
   (b) How much time has elapsed on the astronauts' chronometers?

5. At what speed, as a fraction of c, will a moving rod have a length 70% that of an identical rod at rest?

6. Jill claims that her new rocket is 100 m long. As she flies past your house, you measure the rocket's length and find that it is only 80 m.
   (a) Should Jill be cited for exceeding the 0.5c speed limit?

7. Our Milky Way galaxy is 100000 ly in diameter. A spaceship crossing the galaxy measures the galaxy's diameter to be a mere 1.0 ly.
   (a) What is the speed of the spaceship relative to the galaxy?
   (b) How long is the crossing time as measured in the galaxy's reference frame?

8. A rocket cruising past earth at 0.3c shoots a bullet out the back door, opposite the rocket's motion, at 0.9c relative to the rocket. What is the bullet's speed relative to the earth?

9. A solar flare blowing out from the sun at 0.9c is overtaking a rocket as it flies away from the sun at 0.8c. According to the crew on board, with what speed is the flare gaining on the rocket?

10. A proton is accelerated to 0.999c.
    (a) What is the proton's momentum?
    (b) By what factor does the proton's momentum exceed its Newtonian momentum?

11. What are (a) the kinetic energy, (b) the rest energy, and (c) the total energy of a 1.1 gram particle with a speed of 0.5c?

12. A quarter-pound hamburger with all the fixings has a mass 200 grams. The food energy of the hamburger is 1.8 MJ.
    (a) What is the energy equivalent of the mass of the hamburger?
    (b) By what factor does the energy equivalent exceed the food energy?

13. At what speed is a particle's kinetic energy twice its rest energy?
14. Energy in the sun is produced by the fusion of four protons into a helium nucleus. The process involves several steps, but the net reaction is simply $4p \rightarrow ^{4}\text{He} + \text{energy}$. Given this, what can you say about the mass of a helium atom compared to four hydrogen atoms?

- One helium atom has more mass than four hydrogen atoms.
- One helium atom has less mass than four hydrogen atoms.
- One helium atom has the same mass as four hydrogen atoms.