1. **Chapter 22, question 34**: An unstable particle called a positive pion (symbol $\pi^+$) decays in an average time of $2.6 \times 10^{-8}$ s. On average how long will it take the pion to decay (as seen by us) if it is moving relative to us at 95% the speed of light.

2. **Chapter 22, question 35**: How fast should a meter stick be moving in order to suffer Fitzgerald contraction down to a length of 60 cm.

3. Two spaceships (A and B) approach your spacecraft at $v = 0.9c$ from opposite directions. They send out radio messages.
   (a) What is the speed you measure for the radio waves from A and B?
   (b) What is the speed of the radio waves from A as measured by B?
   (c) How fast does spaceship B observe spaceship A to be approaching?

4. **The twin’s paradox of Special Relativity**: Astronauts A and B are twins. Twin-A is selected by NASA for a near light-speed flight to a star which is 10 light years away. She boards a spacecraft which travels at a constant velocity $v = 0.866c$ to the star. She then turns around abruptly (the acceleration is actually quite uncomfortable!) and flies at the same speed back to Earth. Twin-B, in the meantime, remains on Earth (and isn’t very happy about it!).
   (a) From the point of view of twin-B who remains on Earth, how long does it take for twin-A to fly to the star and fly back.
   (b) How long does twin-A think the trip has taken? When they are reunited again, who will be younger?
   (c) Instead of thinking about the spacecraft as flying away from the stationary Earth and then returning, rethink this problem as the Earth flying away from the stationary spacecraft and then returning. With this in mind, describe why this scenario is often referred to as the twin’s paradox.
   (d) What is the solution to this paradox? [Hint — you need to find something that breaks the symmetry between the two points of view.]

5. **A quick trip to Pluto and back**: In the future, NASA proposes to use a new propulsion technology to fly an astronaut to Pluto and back. On route, the spacecraft will have a constant velocity of $400$ km$s^{-1}$ and the round-trip will take 1 year. If an accurate clock is placed on the spacecraft, how much time will it have lost over the course of the whole mission as compared with an identical clock that stays on Earth?
6. **Special Relativity and particle physics**: A physicist at UMd manages to use a particle accelerator to make a new kind of particle. He calls this particle a zoom. In particular, he creates zoom/anti-zoom pairs by colliding together electron/anti-electron pairs.

   (a) He finds that there is just enough energy to create one zoom/anti-zoom pair if the electron and anti-electron each possess a Lorentz factor of \( \gamma = 10^6 \) prior to the collision. What is the mass of the zoom compared with that of an electron?

   (b) After more experiments, she determines that a zoom which is at rest decays after an average lifetime of \( 1.0 \times 10^{-6} \text{ s} \). In a particular experiment, he produces zooms each of which have a Lorentz factor of \( \gamma = 100 \). What is the average distance traveled by a zoom before it decays?

7. **The helium balloon experiment**: Suppose you have a helium-filled balloon floating in a car (maybe tied by a string to the central console). You then accelerate forwards. Does the balloon move towards the front or back of the car? Relate your answer to the equivalence principle.