CHAPTER 37
RELATIVITY

Discussion Questions

Q37.1 (a) The proper time is measured in a frame in which the two events occur at the same place. That is the frame of reference of the moving train; the passenger on the train measures the proper time. (b) The proper length of an object is measured in a frame in which the object is at rest. The proper length of the train car is measured in the frame of the moving train; the passenger on the train measures the proper length. (c) The proper length of the sign is measured in a frame attached to the ground; you measure the proper length of the sign.

Q37.2 No. The effect cannot occur before the cause. In order for event A to cause event B some sort of signal must travel from event A to event B and this signal cannot travel faster than the speed of light. Therefore, if two events are causally related their separation in space and their separation in time in any frame must be such that a light signal can be passed between them. Events that satisfy this constraint occur in the same order in all reference frames. If event A occurs before event B in some frame and B before A in other frames then the space and time intervals between the events in any frame must be such that a light signal cannot be passed between them; they cannot be causally related.

Q37.3 (a) With respect to the astronaut riding with the rocket the light travels the same distance to each wall and the events are simultaneous. (b) Relative to the person at rest on earth, the walls of the rocket move to the right as the light travels to them so the light travels a shorter distance to reach the rear wall and this person observes *B* occurring first.

Q37.4 In the rest frame of the spacecraft the passenger sees her distance from the asteroid increase as the asteroid moves away from her at $0.9c$. Simultaneously, she sees her distance from the earth decrease as the earth moves toward her at $0.9c$. The passenger receives the radio messages simultaneously when her distance from the asteroid is equal to her distance from earth. Therefore, she deduces that the signal from earth was sent at a time when she was farther from earth than she was from the asteroid. Since the signal from the earth must travel a greater distance than the signal from the asteroid, the passenger deduces that the signal from the earth must have been sent before the signal from the asteroid.

Q37.5 No. By a distance of 70 light years we mean a distance between two points measured in the frame of the earth. The separation between these two points is shortened relative to an observer moving very close to the speed of light and such a traveler can travel between the two points in a time, measured in his frame, that is less than 70 years.

Q37.6 You would need to travel at high speed in the direction along the major axis of the ellipse. (See Problem 37.45.)

Q37.7 In the thought experiment of Section 37.2 the two events occur at different places in each frame. If the two events are simultaneous in a frame and occur at the same point in that frame then they are simultaneous in all frames. The effect described in Section 37.2 arises from the differences in travel time of a light signal from each event to the observer.

Q37.8 Larry measures the proper length l_0 of the train car. Adam measures the length *l*, where $l = l_0\sqrt{1-u^2/c^2}$ and *u* is the speed of the train relative to the earth. The length *l* is less than l_0. Since David is moving in the same direction as the train, the speed of the train relative to him is smaller than the train's speed relative to Adam. Therefore, the length contraction is a bit less for David than for Adam, but the difference is very small since the bicycle moves much, much slower than the train. All three observers measure different lengths for the train car. The length measured by Larry is the greatest and the length measured by Adam is the smallest.

Q37.9 No. Eq.(37.27) shows that p increases without bound as v approaches c. Similarly, Eq.(37.38) shows that E increases without bound as v approaches c.

Q37.10 She is correct. As soon as a massless particle, such as a photon, is created, it has speed c. Photons never have speed less than c. Recent experimental evidence suggests that perhaps neutrinos do have mass.

Q37.11 No. Einstein's second postulate is about the speed of light in vacuum.

Q37.12 No. The speed of light is the same for all observers. Both the wavelength and frequency are altered by the motion of the source but they still satisfy $c = f\lambda$. When λ is shortened f is increased and the speed of light is unaffected by the motion of the source.

Q37.13 In principle an increase in energy corresponds to an increase in mass. But the amount of mass associated with ordinary amounts of thermal energy is quite small. For example, $E = mc^2$ says that an energy of 900 J corresponds to a mass of 1×10^{-14} kg. So, in practice this is not a measurable effect.

Q37.14 Common experience involves speeds where Newtonian mechanics applies to high accuracy. Experiments that show a breakdown of Newtonian mechanics are technologically advanced and could only be performed starting in the 20th century. Also, relativistic mechanics is conceptually more complicated and is built on the foundation of Newtonian mechanics. Conceptually, it would have been difficult for scientists to develop relativistic mechanics if they didn't first have a deep understanding of Newtonian mechanics.

Q37.15 The effects of special relativity would be commonplace.