1. Suppose that we send a spaceship on a trip to Alpha Centauri, 4 light-years away. The spaceship travels at a constant speed of $0.5c$, it stops at Alpha Centauri for 1 year, and it then returns to the Earth at constant speed $0.5c$.

(a) Draw a spacetime diagram with axes x, ct and plot the worldline of the spaceship.

(b) Suppose that 1 year after the departure of the spaceship, we send a radio message from the Earth toward the ship. Plot the worldline of this radio signal. At what time does it reach the spaceship?

2. A spaceship moves at a speed of $0.3c$ along the positive x axis relative to the Earth.

(a) For this speed, draw the Minkowski diagram with the coordinate grids x, ct and x', ct' as in Fig. 2.15. Be sure to draw the correct angle for the x', ct' axes and to draw the correct calibration for these axes.

(b) On your diagram, mark the spacetime point $x = 2$, $ct = 4$. Determine the values of x' and ct' for this point graphically, by means of your coordinate grid.

(c) On your diagram, plot the worldline of an electron moving with velocity $v_x = 0.5c$. What is the slope of this worldline relative to the x, ct axes? Graphically determine the slope of the worldline relative to the x', ct' axes and thereby find v'_x.

(*d*) Compare the values of your graphical determinations in (b) and (c) with the numerical computations of these values from Eqs. (12), (13), and (35).

3. Consider a spaceship that moves at a speed of $0.4c$ along the *negative* x axis relative to the Earth. Draw the Minkowski diagram for this case. How does it differ from the Minkowski diagram for a speed along the positive x axis?

4. Astronomers on the Earth (regarded as an inertial reference frame) see two novas flare up simultaneously. One of the novas is at a distance of 1.0×10^3 light-years in the constellation Draco; the other nova is at an equal distance in the constellation Tucana in a direction (as see from the Earth) exactly opposite to that of the first nova. According to astronomers aboard an aircraft traveling at 750 km/h along the line from Draco to Tucana, the novas are not simultaneous. According to these astronomers, which nova happened first? By how many hours?

5. A spaceship has a speed of $0.80c$ relative to the Earth. In its own reference frame, the length of this spaceship is 300 m.

(a) Consider a pulse of light emitted from the tail of this spaceship. In the reference frame of the spaceship, how long does this pulse take to reach the nose?

(b) In the reference frame of the Earth, how long does this take? Calculate this time directly from the motions of the spaceship and the light pulse; then recalculate it by applying the Lorentz transformations to the result obtained in (a).

7. (a) Suppose that we install an array of mirrors along the equator of the Earth, so as to compel a light ray to travel along the equator all the way around the Earth. From one point on the equator, we send a light signal westward around the Earth and another light signal eastward around the Earth. Taking into account the rotation of the Earth, which of these signals returns to the starting point first? By how many seconds?

(b) The result of part (a) is in conflict with a universal, constant value of the speed of light in the reference frame of the ground, and it tells us that on the rotating Earth we cannot synchronize clocks by light signals, according to the standard procedure described in Section 2.2. Does this contradict the Principle of Relativity?

10. Two wheels are welded to the ends of a rigid straight shaft of length L aligned with the x axis (see Fig. 2.21). According to the manufacturer's specifications, in the rest frame of the shaft, corresponding spokes of the wheels are parallel, as indicated by the parallel dashed lines in the figure. Suppose that in the laboratory frame, the shaft and wheels have no translational motion, but they rotate rigidly with angular velocity ω. In a spaceship frame moving toward the left at speed V (in which the wheels move toward the right at the same speed V), what is the angular displacement between the corresponding spokes of the two wheels measured at one instant of t' time?

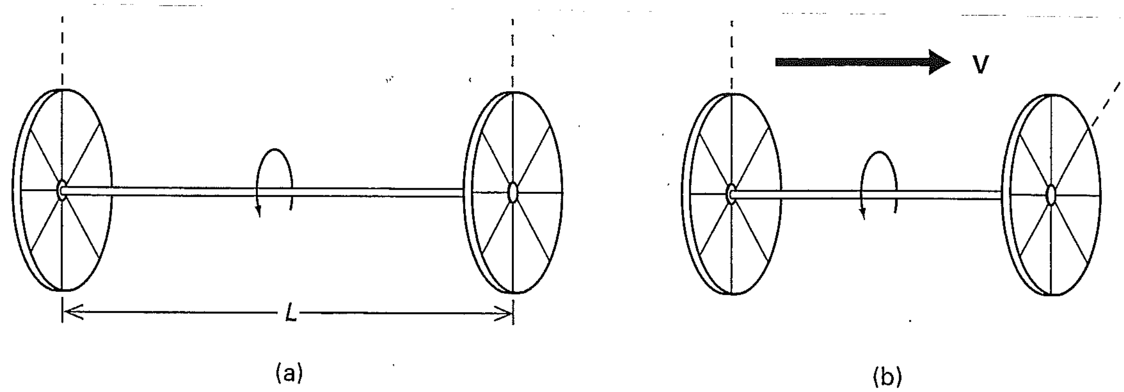

Fig. 2.21 Two wheels welded to a rigid shaft. (a) In the laboratory frame the shaft is at rest, and the spokes of the wheels are aligned. (b) In the spaceship frame the shaft moves toward the right at speed V, and at one instant of t' time, the spokes are misaligned.

17. In the reference frame of the Earth, a meter rod is placed at rest in the x-y plane. The meter rod makes an angle ϕ with the x axis (see Fig. 2.24). What angle ϕ' does this meter rod make with the x' axis of a spaceship traveling at speed V along the x axis of the Earth frame? Evaluate numerically for $\phi = 30^0$ and $V = 0.8c$.

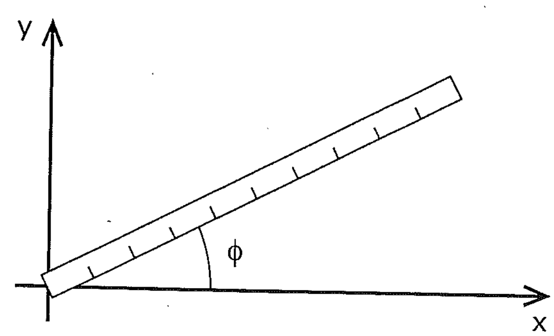

Fig. 2.24 A meter rod in the x-y plane, inclined at an angle ϕ.

20. In the laboratory frame, two events are separated by a time interval of 8.0 s and a spatial distance of 2.0×10^9 m. Does there exist a spaceship frame in which the two events are simultaneous? Does there exist a spaceship frame in which the two events occur at the same point of space? In such a spaceship frame, what is the spatial distance or the time interval between the two events?