32. (II) What is the speed of an electron whose kinetic energy is 1.00 MeV?

33. (II) What is the speed of an electron just before it hits a television screen after being accelerated from rest by the 25,000 V of the picture tube?

34. (II) Two identical particles of rest mass m_0 approach each other at equal and opposite speeds, v. The collision is completely inelastic and results in a single particle at rest. What is the rest mass of the new particle? How much energy was lost in the collision? How much kinetic energy is lost in this collision?

35. (II) Calculate the speed of a proton $(m_0 = 1.67 \times 10^{-27}\,\text{kg})$ whose kinetic energy is exactly half (*a*) its total energy, (*b*) its rest energy.

36. (II) What is the speed and the momentum of an electron $(m = 9.11 \times 10^{-31}\,\text{kg})$ whose kinetic energy equals its rest energy?

37. (II) Suppose a spacecraft of mass 27,000 kg is accelerated to $0.21c$. (*a*) How much kinetic energy would it have? (*b*) If you used the classical formula for kinetic energy, by what percentage would you be in error?

38. (II) Calculate the kinetic energy and momentum of a proton $(m_0 = 1.67 \times 10^{-27}\,\text{kg})$ traveling $7.35 \times 10^7\,\text{m/s}$. By what percentages would your calculations have been in error if you had used classical formulas?

39. (II) The americium nucleus, $^{241}_{95}\text{Am}$, decays to a neptunium nucleus, $^{237}_{93}\text{Np}$, by emitting an alpha particle of mass 4.00260 u and kinetic energy 5.5 MeV. Estimate the mass of the neptunium nucleus, ignoring its recoil, given that the americium mass is 241.05682 u.

40. (II) An electron $(m_0 = 9.11 \times 10^{-31}\,\text{kg})$ is accelerated from rest to speed v by a conservative force. In this process, its potential energy decreases by $6.60 \times 10^{-14}\,\text{J}$. Determine the electron's speed, v.

41. (II) Make a graph of the kinetic energy versus momentum for (*a*) a particle of nonzero rest mass, and (*b*) a particle with zero rest mass.

42. (II) What magnetic field intensity is needed to keep 998-GeV protons revolving in a circle of radius 1.0 km (at, say, the Fermilab synchrotron)? Use the relativistic mass. The proton's rest mass is $0.938\,\text{GeV}/c^2$. $(1\,\text{GeV} = 10^9\,\text{eV}.)$ [*Hint*: in relativity, it is still true that $mv^2/r = qvB$ in a magnetic field.]

26–10 Relativistic Addition of Velocities

43. (I) A person on a rocket traveling at $0.50c$ (with respect to the Earth) observes a meteor come from behind and pass her at a speed she measures as $0.50c$. How fast is the meteor moving with respect to the Earth?

44. (II) Two spaceships leave Earth in opposite directions, each with a speed of $0.50c$ with respect to Earth. (*a*) What is the velocity of spaceship 1 relative to spaceship 2? (*b*) What is the velocity of spaceship 2 relative to spaceship 1?

45. (II) A spaceship leaves Earth traveling at $0.71c$. A second spaceship leaves the first at a speed of $0.87c$ with respect to the first. Calculate the speed of the second ship with respect to Earth if it is fired (*a*) in the same direction the first spaceship is already moving, (*b*) directly backward toward Earth.

46. (II) An observer on Earth sees an alien vessel approach at a speed of $0.60c$. The *Enterprise* comes to the rescue (Fig. 26–12), overtaking the aliens while moving directly toward Earth at a speed of $0.90c$ relative to Earth. What is the relative speed of one vessel as seen by the other?

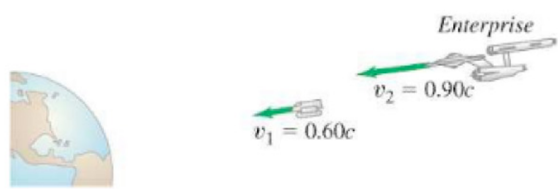

FIGURE 26–12 Problem 46.

47. (II) A spaceship in distress sends out two escape pods in opposite directions. One travels at a speed $v_1 = -0.60c$ in one direction, and the other travels at a speed $v_2 = +0.70c$ in the other direction, as observed from the spaceship. What speed does the first escape pod measure for the second escape pod?

48. (II) Rocket A passes Earth at a speed of $0.75c$. At the same time, rocket B passes Earth moving $0.95c$ relative to Earth in the same direction. How fast is B moving relative to A when it passes A?

General Problems

49. The nearest star to Earth is Proxima Centauri, 4.3 light-years away. (*a*) At what constant velocity must a spacecraft travel from Earth if it is to reach the star in 4.0 years, as measured by travelers on the spacecraft? (*b*) How long does the trip take according to Earth observers?

50. As a rule of thumb, anything traveling faster than about $0.1c$ is called *relativistic*—i.e., for which the correction using special relativity is a significant effect. Determine the speed of an electron in a hydrogen atom (radius $0.5 \times 10^{-10}\,\text{m}$) and state if it is relativistic. (Treat the electron as though it were in a circular orbit around the proton.)

51. (*a*) What is the speed v of an electron whose kinetic energy is 14,000 times its rest energy? You can state the difference, $c - v$. Such speeds are reached in the Stanford Linear Accelerator, SLAC. (*b*) If the electrons travel in the lab through a tube 3.0 km long (as at SLAC), how long is this tube in the electrons' reference frame? [*Hint*: use the binomial expansion.]

52. How many grams of matter would have to be totally destroyed to run a 100-W lightbulb for 1 year?

53. What minimum amount of electromagnetic energy is needed to produce an electron and a positron together? A positron is a particle with the same rest mass as an electron, but has the opposite charge. (Note that electric charge is conserved in this process. See Section 27–6.)