Section 28.1 Events and Inertial Reference Frames
Section 28.2 The Postulates of Special Relativity
Section 28.3 The Relativity of Time: Time Dilation

1. At time $t = 2.3$ s, a 4-kg block that initially moves with a constant speed of 6 m/s undergoes an inelastic collision with another block. Any two inertial observers must agree that
   (a) the event took place at $t = 2.3$ s.
   (b) the initial speed of the block is 6 m/s.
   (c) the initial momentum of the block has magnitude 24 kg•m/s.
   (d) the second block is moving after the collision.
   (e) the momentum of the two block system is conserved during the collision.

2. Which one of the following systems would constitute an inertial reference frame?
   (a) a weather balloon descending at constant velocity
   (b) a rocket undergoing uniform acceleration
   (c) a train rounding a turn at constant speed
   (d) an orbiting space station
   (e) a rotating merry-go-round

3. Which one of the following is a consequence of the postulates of special relativity?
   (a) There is no such thing as an inertial reference frame.
   (b) Newton's laws of motion apply in every reference frame.
   (c) Coulomb's law of electrostatics applies in any reference frame.
   (d) The question of whether an object is at rest in the universe is meaningless.
   (e) The value of every physical quantity depends on the reference frame in which it is measured.

4. Complete the following statement: The Michelson-Morley experiment
   (a) confirmed that time dilation occurs.
   (b) proved that length contraction occurs.
   (c) verified the conservation of momentum in inertial reference frames.
   (d) supported the relationship between mass and energy.
   (e) indicated that the speed of light is the same in all inertial reference frames.

5. Danelle is moving in a spaceship at a constant velocity away from a group of stars. Which one of the following statements indicates a method by which she can determine her absolute velocity through space?
   (a) She can measure her increase in mass.
   (b) She can measure the contraction of her ship.
   (c) She can measure the vibration frequency of a quartz crystal.
   (d) She can measure the change in total energy of her ship.
   (e) She can perform no measurement to determine this quantity.

6. Which one of the following statements concerning the proper time interval between two events is true?
   (a) It is the longest time interval that any inertial observer can measure for the event.
   (b) It is the shortest time interval that any inertial observer can measure for the event.
   (c) It is the time measured by an observer who is in motion with respect to the event.
   (d) Its value depends upon the speed of the observer.
   (e) Its value depends upon the choice of reference frame.
7. Which one of the following statements concerning *time dilation* is true?
(a) It is predicted by special relativity, but has never been observed.
(b) It has been observed only in experiments involving radioactive decay processes.
(c) It has been observed in experiments involving both atomic clocks and radioactive decay processes.
(d) It was demonstrated by the Michelson-Morley experiment.
(e) It has been disproved in experiments with atomic clocks.

8. Which one of the following statements is a consequence of Special Relativity?
(a) Clocks that are moving run slower than when they are at rest.
(b) The length of a moving object is larger than it was at rest.
(c) Events occur at the same coordinates for observers in all inertial reference frames.
(d) Events occur at the same time for observers in all inertial reference frames.
(e) The speed of light has the same value for observers in all reference frames.

9. Two helium-filled balloons are released simultaneously at points A and B on the x axis in an earth-based reference frame. Which one of the following statements is true for an observer moving in the +x direction?
(a) The observer always sees the balloons released simultaneously.
(b) The observer could see either balloon released first depending on her speed and the distance between A and B.
(c) The observer sees balloon A released before balloon B.
(d) The observer sees balloon B released before balloon A.
(e) The observer cannot determine whether they were released separately or simultaneously.

10. In the year 2100, an astronaut wears an antique, but accurate, “quartz” wristwatch on a journey at a speed of $2.0 \times 10^8$ m/s. According to mission control in Houston, the trip lasts 12 hours. How long was the trip as measured on the watch?
(a) 6.7 hr  (c) 12.0 hr  (e) 21.6 hr
(b) 8.9 hr  (d) 16.1 hr

11. In a science fiction novel, a starship takes three days to travel between two distant space stations according to its own clocks. Instruments on one of the space stations indicate that the trip took four days. How fast did the starship travel, relative to the space station?
(a) $1.98 \times 10^8$ m/s  (c) $2.51 \times 10^8$ m/s  (e) $2.99 \times 10^8$ m/s
(b) $2.24 \times 10^8$ m/s  (d) $2.83 \times 10^8$ m/s

12. The proper mean lifetime of a muon is $2.2 \times 10^{-6}$ s. A beam of muons is moving with speed $0.6c$ relative to an inertial observer. How far will a muon in the beam travel, on average, before it decays?
(a) 288 m  (c) 500 m  (e) 800 m
(b) 360 m  (d) 600 m

13. A bomb is designed to explode 2.00 s after it is armed. The bomb is launched from earth and accelerated to an unknown final speed. After reaching its final speed, however, the bomb is observed by people on earth to explode 4.25 s after it is armed. What is the final speed of the bomb just before it explodes?
(a) $0.995c$  (c) $0.939c$  (e) $0.882c$
(b) $0.971c$  (d) $0.904c$
14. During a baseball game, a batter hits a ball directly back to the pitcher who catches it. An observer flying over the stadium at a speed of 0.75c, measures 0.658 s as the time between the two events (hitting and catching the ball). What is the proper time interval between the two events?
(a) 0.288 s  
(b) 0.435 s  
(c) 0.658 s  
(d) 0.715 s  
(e) 0.994 s

15. A spaceship traveling at 0.8550c relative to the Earth monitors a motorcycle drag race on Earth. The space travelers measure the time from the start to the finish of the race to be 14.46 s. What is the proper time interval for the motorcycle race?
(a) 7.499 s  
(b) 8.348 s  
(c) 10.22 s  
(d) 14.46 s  
(e) 27.90 s

16. Mars rotates about its axis once every 88 642 s. A spacecraft comes into the solar system and heads directly toward Mars at a speed of 0.800c. What is the rotational period of Mars according to the beings on the spaceship?
(a) 53 100 s  
(b) 88 600 s  
(c) 105 000 s  
(d) 148 000 s  
(e) 181 000 s

Section 28.4 The Relativity of Length: Length Contraction

17. Complete the following statement: To measure the proper length of an object moving relative to the surface of the earth, one must note the coordinates of points on the front and back ends
(a) at the same time with respect to a clock at rest on the earth.  
(b) at different times with respect to a clock on the moving object.  
(c) at the same time with respect to a clock on the moving object.  
(d) at different times with respect to a clock at rest on the earth.  
(e) at the same time with respect to a clock moving at the same speed on the surface of the earth.

18. Which one of the following statements concerning the proper length of a meter stick is true?
(a) The proper length is always one meter.  
(b) The proper length depends upon the speed of the observer.  
(c) The proper length depends upon the acceleration of the observer.  
(d) The proper length depends upon the reference frame in which it is measured.  
(e) The proper length is the length measured by an observer who is moving with respect to the meter stick.

19. A meter stick is observed to be only 0.900 meters long to an inertial observer. At what speed, relative to the observer, must the meter stick be moving?
(a) 0.44 \times 10^8 m/s  
(b) 0.57 \times 10^8 m/s  
(c) 0.95 \times 10^8 m/s  
(d) 1.31 \times 10^8 m/s  
(e) 2.70 \times 10^8 m/s

20. A UFO flies directly over a football stadium at a speed of 0.50c. If the proper length of the field is 100 yards, what field length is measured by the crew of the UFO?
(a) 59 yards  
(b) 75 yards  
(c) 87 yards  
(d) 113 yards  
(e) 121 yards

21. A spaceship leaves our solar system at a constant speed of 0.900c and travels to a point in the Andromeda galaxy. According to astronomers in an inertial reference frame on Earth, the distance to the galaxy is 2.081 \times 10^{22} m. What distance does the crew on the ship measure on its journey?
(a) 9.07 \times 10^{21} m  
(b) 9.85 \times 10^{21} m  
(c) 1.91 \times 10^{22} m  
(d) 2.83 \times 10^{22} m  
(e) 4.77 \times 10^{22} m
22. The Milky Way galaxy is a part of a group of galaxies called the Local Group. The proper distance from the Milky Way, on one side of the Local Group, to the M31 galaxy on the other side is approximately $2.4 \times 10^6$ light-years. How long (in years) would it take a spaceship traveling at $0.999c$ to travel this distance according to travelers onboard?

(a) $2.4 \times 10^6$ years  
(b) $8.4 \times 10^5$ years

(c) $1.1 \times 10^5$ years  
(d) $5.6 \times 10^4$ years

(e) $2.0 \times 10^4$ years

Section 28.5 Relativistic Momentum

23. A proton has a mass of $1.673 \times 10^{-27}$ kg. If the proton is accelerated to a speed of $0.93c$, what is the magnitude of the relativistic momentum of the proton?

(a) $6.2 \times 10^{-17}$ kg $\cdot$ m/s  
(b) $1.3 \times 10^{-18}$ kg $\cdot$ m/s

(c) $4.7 \times 10^{-19}$ kg $\cdot$ m/s  
(d) $5.9 \times 10^{-24}$ kg $\cdot$ m/s

(e) $1.6 \times 10^{-27}$ kg $\cdot$ m/s

24. An electron gun inside a computer monitor sends an electron toward the screen at a speed of $1.20 \times 10^8$ m/s. If the mass of the electron is $9.109 \times 10^{-31}$ kg, what is the magnitude of its relativistic momentum?

(a) $9.88 \times 10^{-23}$ kg $\cdot$ m/s  
(b) $1.09 \times 10^{-22}$ kg $\cdot$ m/s

(c) $1.19 \times 10^{-22}$ kg $\cdot$ m/s  
(d) $1.41 \times 10^{-22}$ kg $\cdot$ m/s

(e) $3.25 \times 10^{-22}$ kg $\cdot$ m/s

25. In the distant future, a $5.40 \times 10^5$-kg intergalactic ship leaves Earth orbit and accelerates to a constant speed of $0.92c$. Determine the difference, $p - p_0$, between the relativistic and classical momenta of the ship.

(a) $3.9 \times 10^{14}$ kg $\cdot$ m/s  
(b) $2.3 \times 10^{14}$ kg $\cdot$ m/s

(c) $8.0 \times 10^{13}$ kg $\cdot$ m/s  
(d) $5.8 \times 10^{13}$ kg $\cdot$ m/s

(e) $1.2 \times 10^{13}$ kg $\cdot$ m/s

26. The momentum of an electron is $1.60$ times larger than the value computed non-relativistically. What is the speed of the electron?

(a) $2.94 \times 10^8$ m/s  
(b) $2.76 \times 10^8$ m/s

(c) $2.61 \times 10^8$ m/s  
(d) $2.34 \times 10^8$ m/s

(e) $1.83 \times 10^8$ m/s

Section 28.6 The Equivalence of Mass and Energy

27. Determine the total energy of an electron traveling at $0.98c$.

(a) $0.25$ MeV  
(b) $0.51$ MeV

(c) $0.76$ MeV  
(d) $1.8$ MeV

(e) $2.6$ MeV

28. Determine the speed at which the kinetic energy of an electron is equal to twice its rest energy.

(a) $0.45c$  
(b) $0.63c$

(c) $0.87c$  
(d) $0.94c$

(e) $0.99c$

29. A muon has rest energy $105$ MeV. What is its kinetic energy when its speed is $0.95c$?

(a) $37$ MeV  
(b) $47$ MeV

(c) $231$ MeV  
(d) $441$ MeV

(e) $741$ MeV
30. A space ship at rest on a launching pad has a mass of \(1.00 \times 10^5\) kg. How much will its energy have increased when the ship is moving at \(0.600c\)?

(a) \(1.12 \times 10^{21}\) J  
(b) \(1.62 \times 10^{21}\) J  
(c) \(2.25 \times 10^{21}\) J  
(d) \(6.00 \times 10^{21}\) J  
(e) \(9.00 \times 10^{21}\) J

31. The rest energies of three subatomic particles are:

Particle \(X\): 107 MeV;  
Particle \(Y\): 140 MeV;  
Particle \(Z\): 0.51 MeV.

Which one of the following statements is necessarily true concerning these three particles?

(a) Particle \(Z\), at rest, could decay into particle \(X\) and give off electromagnetic radiation.  
(b) Particle \(X\), at rest, could decay into particle \(Y\) and give off electromagnetic radiation.  
(c) Particle \(X\), at rest, could decay into particles \(Y\) and \(Z\) and give off electromagnetic radiation.  
(d) Particle \(Y\), at rest, could decay into particles \(X\) and \(Z\) and give off electromagnetic radiation.  
(e) Particle \(Z\), at rest, could decay into particles \(X\) and \(Y\) and give off electromagnetic radiation.

32. The temperature of a 5.00-kg lead brick is increased by 225°C. If the specific heat capacity of lead is 128 J/(kg • C°), what is the increase in the mass of the lead brick when it has reached its final temperature?

(a) \(4.33 \times 10^{-11}\) kg  
(b) \(9.66 \times 10^{-11}\) kg  
(c) \(1.60 \times 10^{-12}\) kg  
(d) \(2.40 \times 10^{-12}\) kg  
(e) \(4.80 \times 10^{-4}\) kg

33. How much energy would be released if 1.0 g of material were completely converted into energy?

(a) \(9 \times 10^8\) J  
(b) \(9 \times 10^9\) J  
(c) \(9 \times 10^{11}\) J  
(d) \(9 \times 10^{13}\) J  
(e) \(9 \times 10^{16}\) J

34. A particle travels at 0.60c. Determine the ratio of its kinetic energy to its rest energy.

(a) 0.25  
(b) 0.50  
(c) 0.60  
(d) 0.64  
(e) 0.80

35. The average power output of a nuclear power plant is \(5.00 \times 10^2\) MW. In one minute, what is the change in the mass of the nuclear fuel due to the energy being taken from the reactor? Assume 100% efficiency.

(a) \(9.3 \times 10^{-17}\) kg  
(b) \(9.3 \times 10^{-11}\) kg  
(c) \(3.3 \times 10^{-13}\) kg  
(d) \(3.3 \times 10^{-7}\) kg  
(e) 9.3 kg

36. At what speed is a particle traveling if its kinetic energy is three times its rest energy?

(a) 0.879c  
(b) 0.918c  
(c) 0.943c  
(d) 0.968c  
(e) 0.989c

37. How much energy is required to accelerate a golf ball of mass 0.046 kg initially at rest to a speed of 0.75c?

(a) \(1.2 \times 10^{14}\) J  
(b) \(2.1 \times 10^{15}\) J  
(c) \(6.3 \times 10^{15}\) J  
(d) \(3.6 \times 10^{16}\) J  
(e) \(7.5 \times 10^{16}\) J

38. Calculate the ratio of the relativistic kinetic energy to the classical kinetic energy, \(KE_{rel}/KE_{class}\), for an electron (mass = \(9.109 \times 10^{-31}\) kg) moving with a constant speed of 0.75c.

(a) 1.8  
(b) 1.6  
(c) 1.4  
(d) 0.74  
(e) 0.56
39. During each hour of flight, a large jet airplane consumes 3330 gallons of fuel via combustion. Combustion releases $1.25 \times 10^6$ joules/gallon. One gallon of fuel has a mass of 2.84 kg. Calculate the energy equivalent of 3330 gallons of fuel and determine the ratio (in percent) of this energy equivalent to the amount of energy released by combustion in one hour of flight.

(a) $7.63 \times 10^{-6}$ %  
(b) $1.20 \times 10^{-7}$ %  
(c) $2.42 \times 10^{-8}$ %  
(d) $6.75 \times 10^{-9}$ %  
(e) $4.89 \times 10^{-10}$ %

Questions 40 through 44 pertain to the situation described below:

A subatomic particle X spontaneously decays into two particles, A and B, each of rest energy $1.40 \times 10^2$ MeV. The particles fly off in opposite directions, each with speed $0.827c$ relative to an inertial reference frame S.

40. Determine the total energy of particle A.

(a) 109 MeV  
(b) 140 MeV  
(c) 200 MeV  
(d) 249 MeV  
(e) 314 MeV

41. Determine the kinetic energy of particle B (relative to frame S).

(a) 109 MeV  
(b) 140 MeV  
(c) 206 MeV  
(d) 249 MeV  
(e) 314 MeV

42. Which one of the following statements concerning particle X is true?

(a) Momentum conservation requires that it was moving in frame S.
(b) Energy conservation requires that it must have been at rest in frame S.
(c) Momentum conservation requires that it must have been at rest in frame S.
(d) Energy conservation requires that its total energy was 280 MeV in frame S.
(e) There is not enough information to determine its state of motion at the time of the decay.

43. Which expression gives the momentum of particle A (relative to frame S)?

(a) $109 \text{ MeV}/c$  
(b) $140 \text{ MeV}/c$  
(c) $206 \text{ MeV}/c$  
(d) $249 \text{ MeV}/c$  
(e) $314 \text{ MeV}/c$

44. Use energy conservation to determine the rest energy of particle X.

(a) 206 MeV  
(b) 249 MeV  
(c) 280 MeV  
(d) 392 MeV  
(e) 498 MeV

Section 28.7 The Relativistic Addition of Velocities

45. Two spaceships are observed from earth to be approaching each other along a straight line. Ship A moves at 0.40c relative to the earth observer, while ship B moves at 0.50c relative to the same observer. What speed does the captain of ship A report for the speed of ship B?

(a) 0.10c  
(b) 0.75c  
(c) 0.85c  
(d) 0.95c  
(e) 0.99c

46. Spaceship A travels at 0.400c relative to an earth observer. According to the same observer, spaceship A overtakes a slower moving spaceship B that moves in the same direction. The captain of B sees A pass her ship at 0.114c. Determine the speed of B relative to the earth observer.

(a) 0.100c  
(b) 0.214c  
(c) 0.300c  
(d) 0.625c  
(e) 0.700c
47. An earth observer sees an alien ship pass overhead at 0.3c. The ion gun of the alien ship shoots ions straight ahead of the ship at a speed 0.4c relative to the ship. What is the speed of the ions relative to the earth observer?
(a) 0.40c  (c) 0.70c  (e) 0.99c
(b) 0.63c  (d) 0.79c

48. Two rockets, A and B, travel toward each other with speeds 0.5c relative to an inertial observer.

Determine the speed of rocket A relative to rocket B.
(a) 0.2c  (c) 0.6c  (e) c
(b) 0.4c  (d) 0.8c

49. The starship Enterprise approaches the Klingon home world with speed 0.6c relative to the planet. To announce its arrival, the Enterprise sends a message in a projectile that travels toward the planet with speed 0.4c relative to the Enterprise. At what speed does a Klingon at the surface of the planet see the projectile approach?
(a) 0.2c  (c) 0.5c  (e) 0.8c
(b) 0.4c  (d) 0.6c

50. An astronomer on earth observes two galaxies moving away from each other along a line that passes through the earth. The astronomer finds that each is moving with a speed of $2.1 \times 10^8$ m/s relative to the earth. At what speed are the galaxies moving apart relative to each other?
(a) $2.8 \times 10^8$ m/s  (c) $2.1 \times 10^8$ m/s  (e) $1.4 \times 10^8$ m/s
(b) $2.4 \times 10^8$ m/s  (d) $1.8 \times 10^8$ m/s

51. The starship Enterprise approaches the planet Risa at a speed of 0.8c relative to the planet. On the way, it overtakes the intergalactic freighter Astra. The relative speed of the two ships as measured by the navigator on the Enterprise is 0.5c. At what speed is Astra approaching the planet?
(a) 0.3c  (c) 0.6c  (e) 0.99c
(b) 0.5c  (d) 0.92c

52. Rocket A travels with speed 0.800c relative to the earth. Rocket B passes rocket A with speed 0.500c relative to rocket A.

Determine the speed of rocket B relative to the earth. Assume that the earth is an inertial reference frame.
(a) 0.714c  (c) 1.30c  (e) 1.70c
(b) 0.929c  (d) 1.40c
53. Astronomers on Earth, an inertial reference frame, observe galaxies A and B that are moving away from the Earth as shown. The speeds indicated are those measured by the astronomers on Earth.

What is the speed of galaxy B as measured by an observer in galaxy A?
(a) $0.22c$
(b) $0.60c$
(c) $0.71c$
(d) $0.95c$
(e) $1.42c$

Additional Problems

54. Complete the following statement: The results of special relativity indicate that
(a) Newtonian mechanics is a valid approximation at low speeds ($v \ll c$).
(b) the laws of electromagnetism are invalid at speeds that are comparable to that of light.
(c) Newtonian mechanics is an incorrect theory.
(d) moving clocks run fast compared to when they are at rest.
(e) moving objects appear to be longer than when they are at rest.

55. A cubic asteroid with proper side length 10.0 m is stationary in an inertial reference frame $S$. A rocket ship moves along one side of the asteroid as shown in the figure with speed $0.80c$ relative to frame $S$. An astronaut in the rocket ship measures the volume of the asteroid. What volume does the astronaut measure?
(a) $220 \text{ m}^3$
(b) $300 \text{ m}^3$
(c) $360 \text{ m}^3$
(d) $600 \text{ m}^3$
(e) $1000 \text{ m}^3$

Questions 56 and 57 pertain to the situation described below:

The rest energy of a block is $E_0$. Relative to inertial observer $O$, the block is moving with speed $v$ so that $\sqrt{1 - \frac{v^2}{c^2}} = \frac{1}{4}$.

56. Which one of the following table entries is correct?

<table>
<thead>
<tr>
<th>Kinetic Energy of Block</th>
<th>Total Energy of Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) $4E_0$</td>
<td>$5E_0$</td>
</tr>
<tr>
<td>(b) $0.75E_0$</td>
<td>$0.25E_0$</td>
</tr>
<tr>
<td>(c) $4E_0$</td>
<td>$4E_0$</td>
</tr>
<tr>
<td>(d) $5E_0$</td>
<td>$4E_0$</td>
</tr>
<tr>
<td>(e) $3E_0$</td>
<td>$4E_0$</td>
</tr>
</tbody>
</table>

57. Observer $O$ finds that the block takes 12 s to go from A to B. How long would this time interval appear to be to an observer riding on the block?
(a) 3 s
(b) 6 s
(c) 12 s
(d) 24 s
(e) 48 s
Questions 58 through 60 pertain to the situation described below:

The figure shows a side view of a galaxy that is 50.0 light years in diameter. This value for the diameter is its proper length. A spaceship enters the galactic plane with speed 0.995c relative to the galaxy. Assume that the galaxy can be treated as an inertial reference frame. **Note:** A light year is the distance that light travels through vacuum in one year; that is, 1 light year = \(c \times 1\) year.

58. How long does it take the spaceship to cross the galaxy according to an observer at rest in the galaxy?
   (a) 5.00 years  (b) 12.5 years  (c) 49.8 years  (d) 50.3 years  (e) 90.0 years

59. How long does it take the spaceship to cross the galaxy according to a clock on board the spaceship?
   (a) 5.02 years  (b) 12.5 years  (c) 49.8 years  (d) 50.3 years  (e) 90.0 years

60. Determine the diameter of the galaxy as perceived by a person in the spaceship.
   (a) 2.49 light years  (b) 3.63 light years  (c) 4.99 light years  (d) 12.4 light years  (e) 36.3 light years

Questions 61 through 63 pertain to the situation described below:

Two rockets, A and B, approach each other as shown in the figure. A travels to the right at 0.7c while B travels to the left at 0.8c. Both speed measurements are made relative to an inertial observer.

61. Determine the speed of A relative to B.
   (a) c  (b) 0.96c  (c) 0.92c  (d) 0.89c  (e) 0.86c

62. Both rockets have a supply of unstable mesons with a mean proper lifetime of \(2.6 \times 10^{-8}\) s. Which one of the following is a correct observation for the inertial observer?
   (a) The mesons in A have a mean lifetime of \(4.3 \times 10^{-8}\) s.
   (b) The mesons in B have a mean lifetime of \(3.6 \times 10^{-8}\) s.
   (c) The mesons in both rockets have a mean lifetime of \(2.6 \times 10^{-8}\) s.
   (d) The mean lifetime of the mesons is the same for both rockets, but less than \(2.6 \times 10^{-8}\) s.
   (e) On average, the mesons in A will decay before the mesons in B.
63. Determine the ratio of the kinetic energy of rocket B to its rest energy.
   (a) 0.80  (c) 0.54  (e) 0.25
   (b) 0.67  (d) 0.33

Questions 64 through 68 pertain to the situation described below:

A space ship traveling east flies directly over the head of an inertial observer who is at rest on the earth's surface. The speed of the space ship is such that \[ \sqrt{1 - \frac{v^2}{c^2}} = \frac{1}{2}. \]

64. The observer is 5 feet tall. According to the navigator of the space ship, how tall is the observer?
   (a) 2.5 ft  (c) 5 ft  (e) 10 ft
   (b) 3.6 ft  (d) 8 ft

65. The navigator of the space ship observes a neon sign on a storefront. If he measures the speed of light emitted from the sign as he approaches the sign, what value will he obtain?
   (a) \(1.5 \times 10^8\) m/s  (c) \(2.2 \times 10^8\) m/s  (e) \(3.0 \times 10^8\) m/s
   (b) \(1.8 \times 10^8\) m/s  (d) \(2.8 \times 10^8\) m/s

66. The navigator's on-board instruments indicate that the length of the space ship is 20 m. If the length of the ship is measured by the inertial earth-bound observer, what value will be obtained?
   (a) 5 m  (c) 20 m  (e) 80 m
   (b) 10 m  (d) 40 m

67. The pilot fires an ion gun that propels ions from the space ship at \(1.0 \times 10^8\) m/s relative to the ship. What is the speed of the ions as measured by the earth observer?
   (a) \(1.0 \times 10^8\) m/s  (c) \(2.4 \times 10^8\) m/s  (e) \(3.0 \times 10^8\) m/s
   (b) \(2.0 \times 10^8\) m/s  (d) \(2.8 \times 10^8\) m/s

68. An apple falls from a tree and takes 4 s to reach the ground as reported by the earth-bound observer. According to the navigator's instruments, how long did it take the apple to fall?
   (a) 1 s  (c) 4 s  (e) 8 s
   (b) 2 s  (d) 6 s