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.

◘ 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.

☐ 5. Jasmine 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.

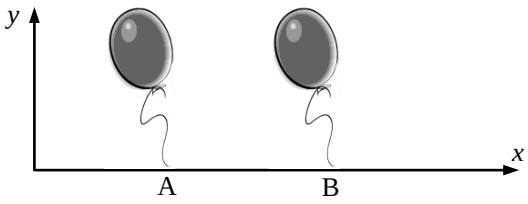
☐ 6. Which one of the following statements concerning the *proper time interval* between two events is true?
(a) It is the longest time interval that any inertial observer can measure for the event.
(b) It is the shortest time interval that any inertial observer can measure for the event.
(c) It is the 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) Time dilation is predicted by special relativity, but has never been observed.
(b) Time dilation has been observed only in experiments involving radioactive decay processes.
(c) Time dilation has been observed in experiments involving both atomic clocks and radioactive decay processes.
(d) Time dilation was demonstrated by the Michelson-Morley experiment.
(e) Time dilation 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 2.0×10^8 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) 1.98×10^8 m/s (c) 2.51×10^8 m/s (e) 2.99×10^8 m/s
(b) 2.24×10^8 m/s (d) 2.83×10^8 m/s

12. The proper mean lifetime of a muon is 2.2×10^{-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 (c) 0.658 s (e) 0.994 s
(b) 0.435 s (d) 0.715 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 (c) 10.22 s (e) 27.90 s

(b) 8.348 s (d) 14.46 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) 0.44×10^8 m/s (c) 0.95×10^8 m/s (e) 2.70×10^8 m/s
(b) 0.57×10^8 m/s (d) 1.31×10^8 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 (c) 87 yards (e) 121 yards
(b) 75 yards (d) 113 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 2.081×10^{22} m. What distance does the crew on the ship measure on its journey?
(a) 9.07×10^{21} m (c) 1.91×10^{22} m (e) 4.77×10^{22} m
(b) 9.85×10^{21} m (d) 2.83×10^{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 2.4×10^6 light-years. How long (in years) would it take a spaceship traveling at $0.999c$ to travel this distance according to travelers onboard?
(a) 2.4×10^6 years (c) 1.1×10^5 years (e) 2.0×10^4 years
(b) 8.4×10^5 years (d) 5.6×10^4 years