***Physics: Principle and Applications*, 7e (Giancoli)**
Chapter 26 The Special Theory of Relativity

26.1 Conceptual Questions

1) Which of the following are *basic postulates* of special relativity? (There could be more than one correct choice.)
A) Nothing can travel faster than the speed of light.
B) No material object can be accelerated to the speed of light.
C) The speed of light is the same for all observers.
D) The laws of physics are the same in all reference frames.
E) The laws of physics are the same in all inertial reference frames.
Answer: C, E
Var: 1

2) If you were in a spaceship traveling close to the speed of light with respect to Earth, you would notice that
A) some of your physical dimensions were smaller than normal.
B) your mass was less than normal.
C) your mass was greater than normal.
D) your pulse rate was greater than normal.
E) none of the above effects occur.
Answer: E
Var: 1

3) You are riding in a spaceship that has no windows, radios, or other means for you to observe or measure what is outside. You wish to determine if the ship is stopped or moving at constant velocity. How can you do this?
A) You can determine if the ship is moving by determining the apparent velocity of light in the spaceship.
B) You can determine if the ship is moving by checking your precision time piece. If it's running slow, the ship is moving.
C) You can determine if the ship is moving by lying down and measuring your height. If you are shorter than usual, the ship is moving.
D) You should give up because you have taken on an impossible task!
Answer: D
Var: 1

4) One of Einstein's postulates in formulating the special theory of relativity was that the laws of physics are the same in reference frames that
A) accelerate.
B) move at constant velocity with respect to an inertial frame.
C) oscillate.
D) are stationary, but not in moving frames.
Answer: B
Var: 1

5) You are a passenger on a spaceship. As the speed of the spaceship increases, you will observe
A) your watch slowing down.
B) your watch speeding up.
C) your watch losing time.
D) your watch gaining time.
E) nothing unusual about the behavior of your watch.
Answer: E
Var: 1

6) A spaceship traveling at constant velocity passes by Earth and later passes by Mars. In which frame of reference is the amount of time separating these two events the proper time?
A) the Earth frame of reference
B) the Mars frame of reference
C) the spaceship frame of reference
D) any inertial frame of reference
E) any frame of reference, inertial or not
Answer: C
Var: 1

7) Observer A sees a pendulum oscillating back and forth in a relativistic rocket and measures its period to be T_A. Observer B moves along with the rocket and measures the period of the pendulum to be T_B. What is true about these two time measurements?
A) $T_A > T_B$
B) $T_A = T_B$
C) $T_A < T_B$
D) T_A could be greater or smaller than T_B depending on the direction of the motion.
Answer: A
Var: 1

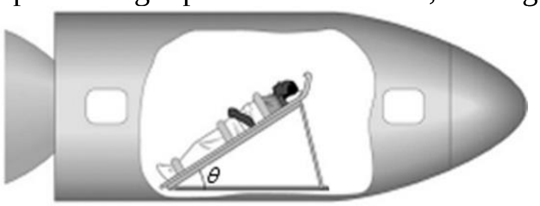
8) A 30-year-old astronaut goes off on a long-term mission in a spacecraft that travels at speeds close to that of light. The mission lasts exactly 20 years as measured on Earth. Biologically speaking, at the end of the mission, the astronaut's age would be
A) more than 50 years.
B) exactly 50 years.
C) less than 50 years.
D) exactly 30 years.
E) exactly 25 years.
Answer: C
Var: 1

9) Suppose one twin takes a ride in a spaceship traveling at a very high speed to a distant star and then back again, while the other twin remains on Earth. Compared to the twin who remained on Earth, the astronaut twin is
A) younger than the Earth-twin.
B) the same age as the Earth-twin.
C) older than the Earth-twin.
D) The ages cannot be determined from the information provided.
Answer: A
Var: 1

10) You are a passenger on a spaceship. As the speed of the spaceship increases, you will observe
A) the length of your spaceship getting shorter.
B) the length of your spaceship getting longer.
C) the length of your spaceship is zero.
D) no change in the length of your spaceship.
Answer: D
Var: 1

11) Observer A sees a ruler moving by in a relativistic rocket and measures its length to be L_A. Observer B moves along with the rocket and measures the length of the ruler to be L_B. What is true about these two length measurements?
A) $L_A > L_B$
B) $L_A = L_B$
C) $L_A < L_B$
D) L_A could be greater or smaller than L_B depending on the direction of the motion.
Answer: C
Var: 1

12) An astronaut is resting on a bed inclined at an angle above the floor of a spaceship, as shown in the figure. From the point of view of an observer who sees the spaceship moving near the speed of light parallel to the floor, the angle the bed makes with the floor



A) is greater than the angle observed by the astronaut.
B) is the same as the angle observed by the astronaut.
C) is smaller than the angle observed by the astronaut.
D) could be greater or smaller than the angle observed by the astronaut depending on whether the rocket is moving to the right or to the left.
Answer: A
Var: 1

13) When an object moves close to the speed of light relative to Earth, what happens to its dimensions compared to what they were before it began moving, as measured by an Earth-based observer?
A) Only lengths parallel to the direction of travel are decreased.
B) Only lengths perpendicular to the direction of travel are decreased.
C) All lengths are decreased.
D) No lengths are affected.
Answer: A
Var: 1

14) A really high-speed train moves in a direction parallel to its length with a speed that approaches the speed of light. The height of the train, as measured by a stationary observer on the ground,
A) approaches infinity.
B) approaches zero.
C) increases slightly.
D) decreases slightly.
E) does not change due to the motion.
Answer: E
Var: 1

15) A really high-speed train moves in a direction parallel to its length with a speed that approaches the speed of light. The length of the train, as measured by a stationary observer on the ground,
A) approaches infinity.
B) increases due to the motion.
C) decreases due to the motion.
D) is not affected by the motion.
Answer: C
Var: 1

16) A spaceship is moving in a straight line away from Earth at $0.80c$, measured relative to Earth. It launches a missile that moves away from the spaceship in the forward direction at $0.60c$, relative to the ship. Relative to Earth, what is the speed of this missile?
A) greater than $0.80c$ but less than c
B) $1.4\ c$
C) c
D) greater than c but less than $1.4c$
Answer: A
Var: 1

17) You are moving at a speed 2/3 *c* toward Randy when shines a light toward you. At what speed do you see the light approaching you?
A) 1/3 *c*
B) 2/3 *c*
C) 4/3 *c*
D) *c*
Answer: D
Var: 1

18) The special theory of relativity predicts that there is an upper limit to the speed of an object. It therefore follows that there is also an upper limit on which of the following properties of the object? (There could be more than one correct choice.)
A) The kinetic energy of the object.
B) The total energy of the object.
C) The linear momentum of the object.
D) None of the above.
Answer: D
Var: 1

19) The relativistic kinetic energy formula is valid
A) only for speeds near the speed of light.
B) at all speeds.
C) only for subatomic particles, such as electrons and protons.
Answer: B
Var: 1

20) According to the equation $E = mc^2$, an object turns into energy when it reaches the speed of light.
A) True
B) False
Answer: B
Var: 1

26.2 Problems

1) An unstable particle is moving at a speed of 1.6×10^8 m/s relative to a laboratory. Its lifetime is measured by a stationary observer in the laboratory to be 6.8×10^{-6} s. What is the lifetime of the particle as measured in the rest frame of the particle? ($c = 3.0 \times 10^8$ m/s)
Answer: 5.8×10^{-6} seconds
Var: 50+

2) A spaceship visits a star that is 4.5 light-years from Earth, and the spaceship travels at one-half the speed of light for the entire trip.
(a) How long did the trip take according to an observer on Earth?
(b) How long did the trip take according to an observer on the spaceship?
Answer: (a) 9.0 light-years (b) 7.8 years
Var: 1

3) How fast (in terms of the speed of light) should a moving clock travel if it is to be observed by a stationary observer as running at one-half its normal rate?
Answer: 0.866*c*
Var: 1

4) A muon at rest decays in 2.2 μs. Moving at 99.00% the speed of light, it would be seen to "live" for how long?
Answer: 16 μs
Var: 1

5) A spaceship carrying a light clock moves at a speed of 0.960*c* relative to an observer on Earth. If the clock on the ship advances by 1.00 s as measured by the space travelers aboard the ship, how long did that advance take as measured by the observer on Earth?
A) 0.96 s
B) 1.2 s
C) 2.6 s
D) 3.6 s
E) 5.8 s
Answer: D
Var: 1

6) Astronaut Rob leaves Earth in a spaceship at a speed of 0.960*c* relative to an observer on Earth. Rob's destination is a star system 14.4 light-years away (one light-year is the distance light travels in one year). Relative to a frame of reference that is fixed with respect to Earth, how long does it take Rob to complete the trip?
A) 14.4 years
B) 15.0 years
C) 10.8 years
D) 4.20 years
E) 22.7 years
Answer: B
Var: 1

7) Astronaut Rachel leaves Earth in a spaceship at a speed of 0.960*c* relative to an observer on Earth. Rachel's destination is a star system 14.4 light-years away (one light-year is the distance light travels in one year). According to Rachel, how long does the trip take?
A) 14 years
B) 15 years
C) 11 years
D) 4.2 years
E) 23 years
Answer: D
Var: 1

8) At age 21, you set out for a star that is 50 light-years from Earth. How fast would your spaceship have to travel in order to reach that star when you are 61 years old? One light-year is the distance light travels in one year.
A) 0.58*c*
B) 0.68*c*
C) 0.78*c*
D) 0.88*c*
E) 0.96*c*
Answer: C
Var: 1

9) A spaceship approaches Earth with a speed 0.50*c*. A passenger in the spaceship measures his heartbeat as 70 beats per minute. What is his heartbeat rate according to an observer that is at rest relative to Earth?
A) 61 beats per minute
B) 65 beats per minute
C) 69 beats per minute
D) 73 beats per minute
E) 75 beats per minute
Answer: A
Var: 5

10) A spaceship enters the solar system moving toward the Sun at a constant speed relative to the Sun. By its own clock, the time elapsed between the time it crosses the orbit of Jupiter and the time it crosses the orbit of Mars is 50.0 minutes. How fast is the spaceship traveling towards the Sun? The radius of the orbit of Jupiter is 778×10^9 m, and that of the orbit of Mars is 228×10^9 m.
A) 0.319*c*
B) 0.438*c*
C) 0.522*c*
D) 0.671*c*
E) 0.982*c*
Answer: C
Var: 5

11) A spaceship enters the solar system moving toward the sun at a constant speed relative to the sun. By its own clock, the time elapsed between the time it crosses the orbit of Jupiter and the time it crosses the orbit of Mars is 50.0 minutes. As measured in the coordinate system of the sun, how long did it take for the spaceship to travel that distance? The radius of the orbit of Jupiter is 778×10^9 m, and that of the orbit of Mars is 228×10^9 m.
A) 30.0 minutes
B) 43.6 minutes
C) 58.6 minutes
D) 69.8 minutes
E) 95.8 minutes
Answer: C
Var: 5

12) A pion is an unstable particle that has a mean lifetime of 2.55×10^{-8} s. This is the time interval between its creation in a nuclear process and its extinction into decay products, as measured in a frame of reference at rest with respect to the pion. An average pion is traveling at 0.230*c* relative to Earth. How far does it travel in its lifetime, relative to Earth?
A) 2.07 m
B) 1.81 m
C) 2.23 m
D) 3.22 m
E) 3.50 m
Answer: B
Var: 5

13) A certain unstable particle has a mean lifetime of 1.52×10^{-6} s. This is the time interval between its creation in a nuclear process and its extinction into decay products, as measured in a frame of reference at rest with respect to the particle. An average such particle is observed by a scientist on Earth to travel 342 m in its lifetime. What is the speed of the particle relative to Earth? ($c = 3.00 \times 10^{8}$ m/s)
A) 0.821*c*
B) 0.681*c*
C) 0.600*c*
D) 0.551*c*
E) 0.335*c*
Answer: C
Var: 1

14) A particle physicist observes cosmic rays creating a new particle high in the atmosphere, and the speed of this particle is measured at 99.7% the speed of light. It is unstable, and is observed to decay in an average 37.0 μs. If this particle were at rest in the laboratory, what would be its average lifetime?
A) 2.9 μs
B) 18 μs
C) 5.3 μs
D) 12 μs
E) 4.3 μs
Answer: A
Var: 1

15) You are moving past the Earth at 0.990c and notice your heart beating 88 beats per minute.
(a) If a doctor on Earth measures your heart rate as you zip past, what will the measured rate be?
(b) If you had been moving 99.99% the speed of light, what rate would you have observed your heart beats?
Answer: (a) 12 beats/min   (b) 88 beats/min
Var: 9

16) As measured in Earth's rest frame, a spaceship traveling at 0.9640*c* takes 10.5 y to travel between two planets that are not moving relative to each other. How long does the trip take as measured by someone on the spaceship?
A) 2.79 y
B) 6.83 y
C) 39.5 y
D) 28.8 y
Answer: A
Var: 50+

17) An astronaut on a spaceship moving at 0.927*c* says that the trip between two stationary stars took 4.26 y. How long does this journey appear to take to someone in the rest frame of the two stars?
A) 11.4 y
B) 1.60 y
C) 2.30 y
D) 12.6 y
Answer: A
Var: 50+

18) Someone in Earth's rest frame says that a spaceship's trip between two planets took 10.0 y, while an astronaut on the space ship says that the trip took 5.78 y. What is the speed of the spaceship, assuming the planets are at essentially at rest?
A) 0.816 c
B) 0.735 c
C) 0.975 c
D) 0.384 c
Answer: A
Var: 50+

19) A spaceship with a constant speed of 0.800*c* relative to Earth travels to a star that is 4.30 light-years from Earth. How much time for this trip would elapse on a clock on board the spaceship?
A) 3.23 y
B) 4.40 y
C) 5.15 y
D) 5.38 y
Answer: A
Var: 1

20) A spaceship with a constant speed of 0.800*c* relative to Earth travels to a star that is 4.30 light-years from Earth. How much time for this trip would elapse on a clock on Earth?
A) 3.23 y
B) 4.40 y
C) 5.15 y
D) 5.38 y
Answer: A
Var: 1

21) A set of twins, Andrea and Courtney, are initially 10 years old. While Courtney remains on Earth, Andrea rides on a spaceship that travels away from Earth at a speed of $0.60c$ for 10 years (as measured by Courtney). At the end of the trip, Courtney is 20 years old. How old is Andrea?
A) 10 years
B) 12 years
C) 18 years
D) 20 years
Answer: C
Var: 1

22) One 20-year-old twin brother takes a space trip with a speed of $0.80c$ for 30 years according to a clock on his spaceship. At the end of this trip, what are (a) his own age and (b) the age of his Earth-based twin brother?
A) (a) 20 y (b) 30 y
B) (a) 30 y (b) 50 y
C) (a) 50 y (b) 70 y
D) (a) 70 y (b) 90 y
Answer: C
Var: 1

23) How fast would a rocket ship have to move past Earth to contract to half of its proper length as observed by an Earth-based physicist?
Answer: $0.87c$
Var: 1

24) A spacecraft is measured by a scientist on the ground to have a length of 81 m as it flies overhead with a speed 2.4×10^8 m/s. The spacecraft then lands and its length is again measured by the scientist at rest on the ground. What result does he now get for the length of the spacecraft? ($c = 3.0 \times 10^8$ m/s)
Answer: 1.4×10^2 m
Var: 50+

25) A stretch of land is 12.5 km long on a map.
(a) What would be its length to an observer moving by, parallel to the stretch, at $0.9500c$?
(b) Which is the proper length for this stretch of land?
(c) How fast relative to Earth would the observer have to move for the land to appear 6.50 km long? Express your answer in terms of the speed of light.
Answer: (a) 3.90 km (b) 12.5 km (c) 0.854c
Var: 8

26) A starship is constructed to be 100 m long in the factory. It is launched and as it coasts by Earth, it is measured to be shortened to 5.48 m long.
(a) How fast, in terms of the speed of light, is it moving past Earth?
(b) What length does the ship's crew measure for the ship?
Answer: (a) $0.9985c$ (b) 100 m
Var: 1

27) Two stars are at rest relative to each other. In their common rest frame, these stars are 90.0 light-years apart. If they are measured to be 68.7 light-years apart by the navigator of a spaceship traveling between them, how fast is the spaceship moving relative to these stars?
A) 0.646*c*
B) 0.604*c*
C) 0.558*c*
D) 0.505*c*
Answer: A
Var: 50+

28) A particle in a 799=m-long linear particle accelerator is moving at 0.875*c*. How long does the particle accelerator appear to the particle?
A) 387 m
B) 1039 m
C) 184 m
D) 1651 m
Answer: A
Var: 50+

29) Two stars are at rest relative to each other. A spaceship is moving between these two stars at 0.932*c* relative to each star. To someone in the ship, the distance between the two stars appears to be 26.4 light-years. What is the distance between the stars in their own rest frame?
A) 72.8 light-years
B) 9.57 light-years
C) 21.1 light-years
D) 55.4 light-years
Answer: A
Var: 50+

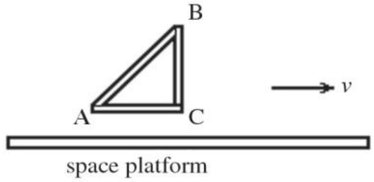
30) Astronaut Jill leaves Earth in a spaceship and is now traveling at a speed of 0.280*c* relative to an observer on Earth. When Jill left Earth, the spaceship was equipped with all kinds of scientific instruments, including a meter stick. Now that Jill is underway, how long does she measure the meter stick to be?
A) 1.00 m
B) 0.960 m
C) 1.04 m
D) 0.280 m
E) 1.28 m
Answer: A
Var: 1

31) How fast must a meter stick move, relative to the frame of the observer making the measurement, so its length will be measured to be 0.60 m?
A) 0.40*c*
B) 0.60*c*
C) 0.70*c*
D) 0.80*c*
E) 0.90*c*
Answer: D
Var: 1

32) Astronaut Sarah leaves Earth in a spaceship at a speed of 0.280*c* relative to Earth. Sarah's destination is a star system 12.5 light-years away (one light-year is the distance light travels in one year). According to Sarah, how far did she travel during the trip?
A) 13.0 light-years
B) 12.5 light-years
C) 12.0 light-years
D) 11.5 light-years
E) 11.0 light-years
Answer: C
Var: 1

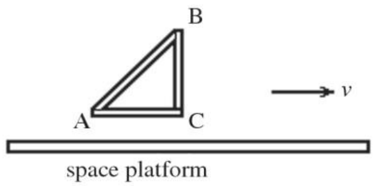
33) Astronaut Hans leaves Earth in a spaceship traveling at a speed of 0.280*c* relative to the observer Brian at rest on Earth. Hans is holding a pencil at an angle of 30° with the direction of travel, as seen by Hans. What angle does the pencil make with the direction of travel, as seen by Brian on Earth?
A) 29°
B) 30°
C) 31°
D) 33°
E) 90°
Answer: C
Var: 1

34) The figure shows a right-angled construction frame ABC. When measured at rest, it has dimensions as follows: AB = 18.9 m, AC = 10.0 m, and BC = 16.0 m. This frame is now given a new velocity of 0.420*c*, relative to Earth, in a direction parallel to AC. How long is part BC of this frame with the new velocity as measured by Earth-based engineers?



A) 16.0 m
B) 14.0 m
C) 12.0 m
D) 10.0 m
E) 18.0 m
Answer: A
Var: 1

35) The figure shows a right-angled construction frame ABC. When measured at rest, it has dimensions as follows: AB = 26.0 m, AC = 10.0 m, and BC = 24.0 m. This frame is now given a new velocity of 0.760*c*, relative to Earth, in a direction parallel to AC. How long is part AC of this frame with the new velocity as measured by Earth-based engineers?



A) 6.50 m
B) 25.4 m
C) 24.3 m
D) 23.7 m
E) 24.9 m
Answer: A
Var: 1

36) A spaceship with a constant velocity of 0.800*c* relative to Earth travels to the star that is 4.30 light-years from Earth. What distance does the space ship travel as measured by a passenger on the ship?
A) 2.58 light-years
B) 3.52 light-years
C) 4.12 light-years
D) 4.30 light-years
Answer: A
Var: 1

37) A person in a rocket ship traveling past the earth at a speed of 0.500*c* fires a laser gun in the forward direction. With what speed does an observer on Earth measure for the light pulse?
Answer: $c = 3.00 \times 10^8$ m/s
Var: 1

38) A rocket is traveling away from Earth at 90% the speed of light. The captain turns on a laser light. What is the speed of the light as measured by an Earth-based astronomer if the captain aims the laser (a) directly forward or (b) directly backward?
Answer: (a) $c = 3.00 \times 10^8$ m/s (b) $c = 3.00 \times 10^8$ m/s
Var: 1

39) Two spaceships are approaching one another, each at a speed of 0.31*c* relative to a stationary observer on Earth. What speed, in terms of the speed of light, does an observer on one spaceship record for the other approaching spaceship?
Answer: 0.57*c*
Var: 50+

40) From the Earth, the Earthlings see the Enterprise approaching from the west at 0.800*c* and the Klingons approaching from the east at 0.900*c*. What speed, in terms of the speed of light, does the crew of the Enterprise measure for the Klingon ship?
Answer: 0.988*c*
Var: 1

41) Two spaceships are traveling through space at speeds of 0.600*c* and 0.900*c*, respectively, with respect to Earth. If they are headed directly toward each other, what is their approach speed (in terms of the speed of light) as measured by the captain of either ship?
Answer: 0.974*c*
Var: 1

42) Two spaceships approach each other along a straight line at a constant *relative* velocity of 0.9880*c* as measured by the captain of one of the ships. An observer on Earth is able to measure the speed of only one of the ships as 0.9000*c*. From the point of view of the observer on Earth, what is the speed of the other ship in terms of the speed of light?
Answer: 0.794*c*
Var: 1

43) A tracking station on Earth observes a rocket move away at 0.370*c*. This rocket is designed to launch a projectile at 0.505*c* relative to the rocket. What speed (in terms of the speed of light) does the tracking station measure for the projectile if it is fired (a) straight ahead of the rocket or (b) backward from the rocket?
Answer: (a) 0.737*c* (b) 0.166*c*
Var: 1

44) A spaceship is moving away from an asteroid with a speed of 0.80c relative to the asteroid. The spaceship then fires a missile with a speed of 0.50c relative to the spaceship. What is the speed of the missile measured by astronauts on the asteroid if the missile is fired away from the asteroid?
A) 0.30c
B) 0.50c
C) 0.93c
D) 1.3c
E) 0.65c
Answer: C
Var: 1

45) A spaceship is moving away from an asteroid with a speed of 0.80c relative to the asteroid. The spaceship then fires a missile with a speed of 0.50c relative to the spaceship. What is the speed of the missile measured by astronauts on the asteroid if the missile is fired toward the asteroid?
A) 0.30c
B) 0.50c
C) 0.93c
D) 1.3c
E) 0.65c
Answer: B
Var: 1

46) A spaceship leaves Earth at a steady forward speed of 70% the speed of light. How fast relative to the ship must the spaceship launch a shuttlecraft in the forward direction so that it will be moving away from Earth at 98.7% the speed of light?
A) 0.91c
B) 0.97c
C) 0.93c
D) 0.99c
E) 0.84c
Answer: C
Var: 1

47) A spaceship traveling at 0.50c away from Earth launches a secondary rocket in the forward direction at 0.50c relative to the spaceship. As measured by Earthlings, how fast is the secondary rocket moving away from Earth?
A) 0.90c
B) 0.50c
C) 0.80c
D) 0.70c
E) c
Answer: C
Var: 1

48) A star is moving toward Earth at 90% the speed of light. The star emits light, which moves away from the star at the speed of light. What do Earth-based astronomers measure for the speed of this light?
A) c
B) $1.9c$
C) $1.2c$
D) $0.98c$
E) $0.95c$
Answer: A
Var: 1

49) A spaceship, traveling at $0.560c$ towards a stationary space platform, launches a secondary towards the station with a speed of $0.100c$ relative to the spaceship. What is the speed of the secondary rocket relative to the space platform?
A) $0.460c$
B) $0.575c$
C) $0.600c$
D) $0.625c$
E) $0.660c$
Answer: D
Var: 1

50) A spaceship, traveling at $0.100c$ away from a stationary space platform, launches a secondary rocket towards the station, with a speed of $0.560c$ relative to the spaceship. What is the speed of the secondary rocket relative to the space platform?
A) $0.460c$
B) $0.487c$
C) $0.492c$
D) $0.550c$
E) $0.660c$
Answer: B
Var: 1

51) Two spaceships approach Earth from the same direction. One has a speed of $0.21c$ and the other a speed of $0.34c$, both relative to Earth. What is the speed of one spaceship relative to the other?
A) $0.13c$
B) $0.14c$
C) $0.15c$
D) $0.16c$
E) $0.18c$
Answer: B
Var: 1

52) Two spaceships approach Earth from opposite directions. One has a speed of 0.21*c* and the other a speed of 0.34*c*, both relative to Earth. What is the speed of one spaceship relative to the other?
A) 0.51*c*
B) 0.55*c*
C) 0.58*c*
D) 0.61*c*
E) 0.64*c*
Answer: A
Var: 1

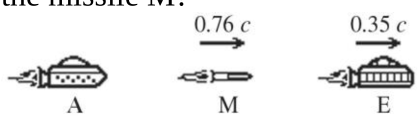
53) Two spaceships, each 100 m long in its own rest frame, approach Earth from opposite directions, each with a speed 0.50*c* relative to Earth. As measured by a passenger in one of the spaceships, how long is the other spaceship?
A) 50 m
B) 60 m
C) 70 m
D) 80 m
E) 90 m
Answer: B
Var: 1

54) Two spaceships, each 100 m long in its own rest frame, approach Earth from opposite directions, with equal speeds relative to Earth. As measured by a passenger in one of the spaceships, the other spaceship is 96 m long. What is the speed of the spaceships relative to Earth?
A) $c/7$
B) $c/6$
C) $c/5$
D) $c/4$
E) $c/3$
Answer: A
Var: 1

55) A spaceship approaching an asteroid at a speed of 0.60*c* launches a scout rocket with speed 0.40*c* relative to the spaceship. At what speed is the scout rocket approaching the asteroid?
A) 0.81*c*
B) 1.0*c*
C) 0.76*c*
D) 0.64*c*
E) 0.96*c*
Answer: A
Var: 1

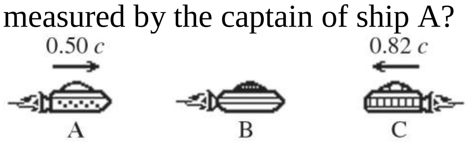
56) In an "atom smasher," two particles collide head on at relativistic speeds. If the velocity of the first particle is 0.741*c* to the left, and the velocity of the second particle is 0.543*c* to the right (both as measured in the lab rest frame), how fast are the particles moving with respect to each other?
A) 0.916*c*
B) 1.284*c*
C) 0.934*c*
D) 0.834*c*
Answer: A
Var: 50+

57) As shown in the figure, the captain of spaceship A observes spaceship E escaping with a relative velocity of 0.35*c*. A missile M is fired from ship A directly toward ship E, with a velocity of 0.76*c* relative to ship A. What does the captain of ship E measure for the velocity of the missile M?



A) 0.56*c*
B) 0.41*c*
C) 0.52*c*
D) 0.48*c*
E) 0.45*c*
Answer: A
Var: 1

58) Three spaceships A, B, and C are in motion as shown in the figure. The commander on ship B observes ship C approaching with a relative velocity of 0.82*c*. The commander also observes ship A, advancing in the rear, with a relative velocity of 0.50*c*. What is the speed of ship C as measured by the captain of ship A?



A) 0.94*c*
B) 0.23*c*
C) 2.2*c*
D) 0.54*c*
E) 1.3*c*
Answer: A
Var: 1

59) Consider three galaxies, Alpha, Beta and Gamma. An astronomer in Beta sees each of the other two galaxies moving away from her in opposite directions at 0.70*c*. At what speed would an observer in Alpha see the galaxy Beta moving?
A) 0.82*c*
B) 0.70*c*
C) 0.94*c*
D) 0.35*c*
E) 0.57*c*
Answer: B
Var: 1

60) Consider three galaxies, Alpha, Beta and Gamma. An astronomer in Beta sees each of the other two galaxies moving away from him in opposite directions at 0.70*c*. At what speed would an observer in Alpha see the galaxy Gamma moving?
A) 0.70*c*
B) 1.4*c*
C) 0.82*c*
D) 0.94*c*
E) 0.98*c*
Answer: D
Var: 1

61) As an electron slows down from 0.9980*c* to 0.5000*c*, how much momentum does it lose? ($c = 3.0 \times 10^{8}$ m/s, $m_{\text{electron}} = 9.11 \times 10^{-31}$ kg)
Answer: 4.2×10^{-21} kg · m.s
Var: 1

62) Calculate the speed at which a 0.723-kg object has the same momentum as a 1.30-kg object that is moving 0.515*c*.
A) 0.734*c*
B) 0.712*c*
C) 0.981*c*
D) 0.592*c*
Answer: A
Var: 50+

63) What is the momentum of a proton when it is moving with a speed of 0.60*c*? ($m_{\text{proton}} = 1.67 \times 10^{-27}$ kg)
A) 1.2×10^{-19} kg· m/s
B) 1.5×10^{-19} kg · m/s
C) 3.0×10^{-19} kg · m/s
D) 3.8×10^{-19} kg · m/s
Answer: D
Var: 1

64) A particle is moving at 0.86*c*. By what magnitude percentage is the Newtonian expression for momentum in error? (The percentage error is the difference between the erroneous and correct expressions, relative the *correct* one).
A) 49%
B) 40%
C) 55%
D) 62%
Answer: A
Var: 46

65) An object with a rest mass of 0.456-kg is moving at 1.20×10^8 m/s. What is the magnitude of its momentum? ($c = 3.00 \times 10^8$ m/s)
A) 5.47×10^7 kg · m/s
B) 5.57×10^7 kg · m/s
C) 5.67×10^7 kg · m/s
D) 5.87×10^7 kg · m/s
E) 5.97×10^7 kg · m/s
Answer: E
Var: 1

66) A satellite, initially at rest in deep space, separates into two pieces, which move away from each other. One piece has a rest mass of 190 kg and moves away with a speed 0.280*c*, and the second piece moves in the opposite direction with a speed 0.600*c*. What is the rest mass of the second piece?
A) 88.7 kg
B) 79.6 kg
C) 73.9 kg
D) 68.8 kg
E) 52.7 kg
Answer: C
Var: 1

67) A satellite, initially at rest in deep space, separates into two pieces, which move away from each other. One piece has a rest mass of 190 kg and moves away with a speed 0.500*c*, and the second piece has a rest mass of 250 kg and moves in the opposite direction. What is the speed of the second piece?
A) 0.212*c*
B) 0.380*c*
C) 0.402*c*
D) 0.473*c*
E) 0.500*c*
Answer: C
Var: 1

68) Two satellites with equal rest masses of 100 kg are traveling toward each other in deep space. They have identical speeds of 0.600*c*. The satellites collide and somehow manage to stick together. What is the rest mass of the combined object after the collision?
A) 200 kg
B) 225 kg
C) 250 kg
D) 275 kg
E) 300 kg
Answer: C
Var: 1

69) A satellite with a rest mass of 200 kg and a speed of 0.800*c* and a second satellite with a rest mass of 100 kg and a speed of 0.600*c* are traveling toward each other in deep space. The satellites collide and somehow manage to stick together. What is the rest mass of the combined object after the collision?
A) 300 kg
B) 389 kg
C) 416 kg
D) 457 kg
E) 587 kg
Answer: C
Var: 1

70) A satellite with a rest mass of 200 kg and a speed of 0.800*c* and a second satellite with a rest mass of 100 kg and a speed of 0.600*c* are traveling toward each other in deep space. The satellites collide and somehow manage to stick together. What is the speed of the combined object after the collision?
A) 0.333*c*
B) 0.374*c*
C) 0.397*c*
D) 0.418*c*
E) 0.432*c*
Answer: D
Var: 1

71) Two satellites with equal rest masses are traveling toward each other in deep space. One is traveling at 0.550*c* and the other at 0.750*c*. The satellites collide and somehow manage to stick together. What is the speed of the combined object after the collision?
A) 0.100*c*
B) 0.113*c*
C) 0.150*c*
D) 0.175*c*
E) 0.311*c*
Answer: D
Var: 5

72) Two satellites with equal rest masses of 100 kg are traveling toward each other in deep space. One is traveling at 0.650*c* and the other at 0.850*c*. The satellites collide and somehow manage to stick together. What is the rest mass of the combined object after the collision?
A) 100 kg
B) 200 kg
C) 277 kg
D) 378 kg
E) 312 kg
Answer: E
Var: 5

73) A proton, which has a mass of 1.67×10^{-27}, is moving at 0.80*c* relative to the laboratory. What does a physicist in that lab measure for its momentum? ($c = 3.0 \times 10^{8}$ m/s)
A) 4.0×10^{-19} kg · m/s
B) 4.4×10^{-19} kg · m/s
C) 5.0×10^{-19} kg · m/s
D) 5.8×10^{-19} kg · m/s
E) 6.7×10^{-19} kg · m/s
Answer: E
Var: 1

74) How much work must be done to accelerate a particle of mass 3.5×10^{-14} kg from a speed of 1.2×10^{8} m/s to a speed of 1.9×10^{8} m/s? ($c = 3.0 \times 10^{8}$ m/s)
Answer: 630 J
Var: 50+

75) An electron has a relativistic momentum of 1.1×10^{-21} kg · m/s. What percent of its total energy is its kinetic energy? ($m_{\text{electron}} = 9.11 \times 10^{-31}$ kg, $c = 3.0 \times 10^{8}$ m/s)
Answer: 76%
Var: 1

76) When a proton is traveling at 0.80*c*, what is the ratio of its kinetic energy to its rest energy?
A) 0.60
B) 0.67
C) 0.80
D) 1.2
E) 1.7
Answer: B
Var: 1

77) If an electron in the lab has a kinetic energy equal to twice its rest energy, what is its speed in the lab?
A) 0.84*c*
B) 0.87*c*
C) 0.89*c*
D) 0.91*c*
E) 0.94*c*
Answer: E
Var: 1

78) Calculate the amount of energy needed to accelerate an electron from $0.888\,c$ to $0.991\,c$. Express your answer in MeV. The rest mass energy of an electron is 0.511 MeV.
A) 2.71 MeV
B) 1.90 MeV
C) 4.61 MeV
D) 5.69 MeV
Answer: A
Var: 50+

79) If the kinetic energy of a proton is 80% of its total energy, what is the speed of the proton?
A) 0.02c
B) 0.87c
C) 0.98c
D) 1.0c
Answer: C
Var: 1

80) What is the total energy of an electron moving with a speed of 0.950*c*? ($c = 3.0 \times 10^8$ m/s, $m_{el} = 9.11 \times 10^{-31}$ kg)
A) 2.6×10^{-13} J
B) 8.2×10^{-14} J
C) 1.1×10^{-13} J
D) 1.2×10^{-14} J
Answer: A
Var: 1

81) How many joules of energy are required to accelerate a 1.0-kg rock from rest to a speed of 0.866*c*? ($c = 3.0 \times 10^8$ m/s)
A) 1.8×10^{17} J
B) 9.0×10^{16} J
C) 3.0×10^{3} J
D) 3.3×10^{16} J
Answer: B
Var: 1

82) If, instead of the correct formula for kinetic energy, we carelessly use the classical expression for kinetic energy for a particle moving at half the speed of light, by what magnitude percent will our calculation be in error? ($c = 3.0 \times 10^8$ m/s)
A) 24%
B) 19%
C) 27%
D) 7%
E) 1%
Answer: B
Var: 1

83) How much energy would be required to accelerate a 77-kg professor from rest to 90% the speed of light? ($c = 3.0 \times 10^8$ m/s)
A) 1.6×10^{19} J
B) 2.1×10^{19} J
C) 9.0×10^{19} J
D) 2.8×10^{19} J
E) 3.5×10^{19} J
Answer: C
Var: 1

84) If the kinetic energy of a particle is 3.00 times its rest energy, the speed of the particle is closest to which of the following values?
A) $0.950c$
B) $0.968c$
C) $0.976c$
D) $0.984c$
E) $0.990c$
Answer: B
Var: 1

85) A space barge pushes on a spaceship with a rest mass of 15,000 kg and accelerates it from a speed of $0.600c$ to a speed of $0.700c$. How much work does the barge have to do to accomplish this? ($c = 3.00 \times 10^8$ m/s)
A) 1.35×10^{20} J
B) 2.03×10^{20} J
C) 2.70×10^{20} J
D) 5.42×10^{20} J
E) 8.78×10^{19} J
Answer: B
Var: 1

86) An electron has a speed of $0.783c$. Through what potential difference would the electron need to be accelerated from rest in order to reach this speed? The rest mass energy of an electron is 0.511 MeV.
A) 310 kV
B) 260 kV
C) 360 kV
D) 400 kV
Answer: A
Var: 50+

87) Consider a student whose mass is 70 kg. If all his mass were converted to electrical energy, for how many years could he keep a 100-W light bulb burning? ($c = 3.0 \times 10^8$ m/s)
Answer: 6.3×10^{16} s = 2.0 billion years!
Var: 1

88) An electron-volt is the energy gained by an electron if it is accelerated through a potential difference of one volt. What is the equivalent to an electron-volt in kilograms? ($c = 3.00 \times 10^8$ m/s, $e = 1.60 \times 10^{-19}$ C)
Answer: 1.78×10^{-36} kg
Var: 1

89) One of the first atomic bombs released energy equivalent to that of 20,000 tons of TNT explosive. How much mass was converted to energy by this explosion, given that 1000 tons of TNT produce 4.3×10^{12} J of energy. Incidentally, modern H-bombs have energy yields 1000 times as much! ($c = 3.0 \times 10^8$ m/s)
Answer: 0.96 g
Var: 1

90) An alpha particle has a mass of 6.64×10^{-27} kg and a charge of 3.20×10^{-19} C, and it is traveling at $0.9650c$. ($c = 3.00 \times 10^8$ m/s), 1 eV = 1.60×10^{-19} J)
(a) What is its rest energy (in GeV)?
(b) What is its total energy (in GeV)?
(c) What is its kinetic energy (in GeV)?
Answer: (a) 3.74 GeV (b) 14.2 GeV (c) 10.5 GeV
Var: 1

91) A person with an initial mass of 70 kg climbs a stairway and thereby rises 6.0 m in elevation. By how much does his mass increase by virtue of his increased potential energy? ($c = 3.0 \times 10^8$ m/s)
Answer: 4.6×10^{-14} kg
Var: 1

92) If the mass of a 1.0-kg book could be entirely converted into electrical energy, how many kW · h of energy would that generate? (c = 3.0 × 10^8 m/s)
Answer: 2.5 × 10^{10} kW · h
Var: 1

93) If a typical city consumes electrical energy at a rate of 2.0 GW, how many kilograms of matter would have to be converted entirely into electrical energy in order to keep this city running for 14 weeks? (c = 3.0 × 10^8 m/s)
A) 0.19 kg
B) 0.21 kg
C) 0.27 kg
D) 0.32 kg
Answer: A
Var: 17

94) In a nuclear plant, 10^{17} J of energy is available from mass conversion. How much mass of fuel was lost to produce this energy? (c = 3.0 × 10^8 m/s)
A) 0.1 kg
B) 1 kg
C) 10 kg
D) 100 kg
Answer: B
Var: 1

95) In a certain chemical reaction, 8.1 × 10^{-19} J of energy is released per molecule formed. What is the difference in mass per molecule between the sum of the masses of the molecules of the reagents before the reaction and the mass of the molecules produced by the reaction? (c = 3.0 × 10^8 m/s)
A) 8.1 × 10^{-28} kg
B) 2.7 × 10^{-27} kg
C) 3.2 × 10^{-27} kg
D) 5.4 × 10^{-32} kg
E) 9.0 × 10^{-36} kg
Answer: E
Var: 1

96) During a reaction, a reactant loses 4.8 × 10^{-28} kg of mass. How many joules of energy are released? (c = 3.0 × 10^8 m/s)
A) 4.3 × 10^{-11} J
B) 1.4 × 10^{-19} J
C) 1.6 × 10^{-36} J
D) 5.3 × 10^{-45} J
Answer: A
Var: 1

97) During a reaction, 170 μJ of energy is released. What change of mass would accompany this release? ($c = 3.0 \times 10^{8}$ m/s)
A) 5.1×10^{-4} kg
B) 1.5×10^{-13} kg
C) 4.8×10^{-18} kg
D) 1.9×10^{-21} kg
Answer: D
Var: 1

98) How many MeV of energy is released during a reaction in which 1.67×10^{-25} kg of material is converted to energy? ($c = 3.0 \times 10^{8}$ m/s, 1 eV = 1.67×10^{-19} J)
A) 5.0×10^{-14} MeV
B) 4.1×10^{-7} MeV
C) 3.1×10^{-4} MeV
D) 9.4×10^{4} MeV
Answer: D
Var: 1

99) How much mass is lost during a reaction in which 1.7×10^{8} MeV of energy is released? ($c = 3.0 \times 10^{8}$ m/s, 1 eV = 1.6×10^{-19} J)
A) 1.8×10^{-8} kg
B) 5.7×10^{-9} kg
C) 1.9×10^{-17} kg
D) 3.0×10^{-22} kg
Answer: D
Var: 1

100) How much energy would be released if 2.0 kg of material was lost during a reaction? ($c = 3.0 \times 10^{8}$ m/s)
A) 1.8×10^{17} J
B) 1.5×10^{16} J
C) 6.0×10^{8} J
D) 4.7×10^{-8} J
Answer: A
Var: 1

101) The energy released by a certain reaction is enough to totally evaporate 125 kg of water at its boiling point. How much mass was lost during this reaction? (L_F = 334,000 J/kg for water, $c = 3.00 \times 10^{8}$ m/s)
Answer: 4.64×10^{-10} kg
Var: 1

102) One of the first atomic explosion released approximately 1.0×10^{14} J of energy. How much matter had to be changed into energy to produce this yield? ($c = 3.0 \times 10^8$ m/s)
A) 1.1 g
B) 23 g
C) 13 g
D) 0.45 kg
E) 1.1 kg
Answer: A
Var: 1

103) A 1.00-kg gold ingot is carried from the bottom of the Eiffel tower to the top, 300 m above ground level. By what amount does its mass change? ($c = 3.00 \times 10^8$ m/s)
A) Its mass does not change.
B) Its mass increases by 3.27×10^{-14} kg
C) Its mass decreases by 3.27×10^{-14} kg
D) Its mass increases by 1.64×10^{-14} kg
E) Its mass decreases by 1.64×10^{-14} kg
Answer: B
Var: 1

104) A 1.0-kg aluminum ingot is heated from 0°C to 100°C. By what amount does its mass change? The specific heat of aluminum is 900 J/kg · K. ($c = 3.0 \times 10^8$ m/s)
A) Its mass does not change.
B) Its mass increases by 0.50×10^{-12} kg
C) Its mass decreases by 0.50×10^{-12} kg
D) Its mass increases by 1.0×10^{-12} kg
E) Its mass decreases by 1.0×10^{-12} kg
Answer: D
Var: 1

105) If a particle has a total energy that is 5.00 times its rest energy, the speed of the particle is closest to which one of the following values?
A) 0.980*c*
B) 0.985*c*
C) 0.950*c*
D) 0.990*c*
E) 0.998*c*
Answer: A
Var: 1

106) The total energy of a moving electron is 0.758 MeV. What is the speed of the electron in terms of *c*? The rest mass energy of an electron is 0.511 MeV.
A) 0.739 *c*
B) 0.794 *c*
C) 0.306 *c*
D) 0.933 *c*
Answer: A
Var: 50+