1) A rocket is moving at 1/4 the speed of light relative to Earth. At the center of this rocket, a light suddenly flashes. To an observer at rest on Earth
A) the light will reach the front of the rocket at the same instant that it reaches the back of the rocket.
B) the light will reach the front of the rocket before it reaches the back of the rocket.
C) the light will reach the front of the rocket after it reaches the back of the rocket.

2) A rocket is moving at 1/4 the speed of light relative to Earth. At the center of this rocket, a light suddenly flashes. To an observer at rest in the rocket,
A) the light will reach the front of the rocket at the same instant that it reaches the back of the rocket.
B) the light will reach the front of the rocket before it reaches the back of the rocket.
C) the light will reach the front of the rocket after it reaches the back of the rocket.

3) An astronaut in an inertial reference frame measures a time interval Δt between her heartbeats. What will observers in all other inertial reference frames measure for the time interval between her heartbeats?
A) Δt B) more than Δt C) less than Δt
D) The answer depends on whether they are moving toward her or away from her.

4) You are a passenger on a spaceship. As the speed of the spaceship increases, you would observe that
A) the length of your spaceship is getting shorter.
B) the length of your spaceship is getting longer.
C) the length of your spaceship is not changing.

5) A star is moving towards the earth with a speed at 90% the speed of light. It emits light, which moves away from the star at the speed of light. Relative to us on earth, what is the speed of the light moving toward us from the star?
A) $0.90c$ B) c C) $1.1c$ D) $1.20c$ E) $1.9c$

6) Astronaut Mark Uri is space-traveling from planet X to planet Y at a speed of $0.65c$ relative to the planets, which are at rest relative to each other. When he is precisely halfway between the planets, a distance of 1.0 light-hour from each one as measured in the planet frame, nuclear devices are detonated on both planets. The explosions are simultaneous in Mark's frame. What is the difference in the time of arrival of the flashes from the explosions as observed by Mark?
A) 0 min B) 180 min C) 90 min
D) 360 min E) 113 min

7) As measured in Earth's rest frame, a spaceship traveling at $0.964c$ takes 11.2 y to travel between planets. How long does the trip take as measured by someone on the spaceship?
A) 2.98 y B) 7.28 y C) 42.1 y D) 30.7 y

8) An astronaut on a spaceship moving at $0.927c$ says that the trip between two stationary stars took 7.49 y. How long does this journey take as measured by someone at rest relative to the two

stars?
A) 20.0 y B) 2.81 y C) 4.05 y D) 22.1 y

9) An unstable particle is moving at a speed of 2.6×10^8 m/s relative to a laboratory. Its lifetime is measured by a stationary observer in the laboratory to be 4.7×10^{-6} seconds. What is the lifetime of the particle, measured in the rest frame of the particle? ($c = 3.00 \times 10^8$ m/s)
Answer: 2.3 μs

10) A spaceship approaches the 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 the earth?
A) 69 beats per minute B) 73 beats per minute
C) 65 beats per minute D) 61 beats per minute
E) 80 beats per minute Answer: D

11) Relative to the frame of the observer making the measurement, at what speed parallel to its length is the length of a meterstick 60 cm?
A) 0.80*c* B) 0.60*c* C) 0.50*c* D) 0.70*c* E) 0.90*c*

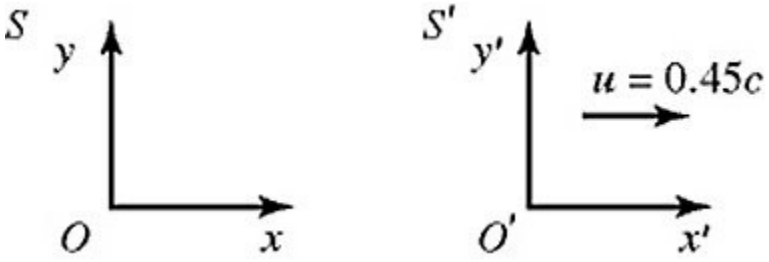
12) In their common rest frame, two stars are 90.0 light-years (ly) apart. If they are 12.0 ly apart as measured by the navigator in a spaceship traveling between them, how fast is the spaceship moving? Express your answer in terms of *c*.
A) 0.991*c* B) 0.986*c* C) 0.980*c* D) 0.972*c*

13) A particle in a 453 m-long linear particle accelerator is moving at $0.875c$. How long does the particle accelerator appear to the particle?
A) 219 m B) 589 m C) 104 m D) 936 m

14) Two space stations are at rest relative to each other and are 6.0×10^7 m apart, as measured by observers on the stations. A spaceship traveling from one station to the other at $0.90c$ relative to the stations passes both of them, one after the other. As measured by an observer in the spaceship, how long does it take to travel from one station to the other? ($c = 3.00 \times 10^8$ m/s)
A) 97 ms B) 220 ms C) 510 ms
D) 58 ms E) 39 ms Answer: A

15) A spacecraft is measured by an observer on the ground to have a length of 53 m as it flies toward the earth with a speed 1.7×10^8 m/s. The spacecraft then lands and its length is again measured by the observer on the ground, this time while the spacecraft is at rest on the launchpad. What result does he now get for the length?

16) System S' has a velocity $u = +0.45c$ relative to system S, as shown in the figure. The clocks of S and S' are synchronized at $t = t' = 0$ when the origins O and O' coincide. An event is observed in both systems. The event takes place at $x = 600$ m and at time $t = 1.9$ μs, as measured by an observer in S. What is the x'-coordinate of the event, measured by an observer in S'?

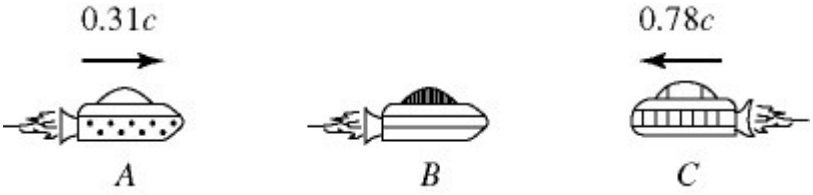


A) 380 m B) 340 m C) 360 m
D) 350 m E) 310 m

17) In an "atom smasher," two particles collide head on at relativistic speeds. If the velocity of the first particle is $0.741c$ to the left, and the velocity of the second particle is $0.350c$ to the right (both of these speeds are measured in Earth's rest frame), how fast are the particles moving with respect to each other?
A) $0.866c$ B) $1.091c$ C) $0.883c$ D) $0.788c$

18) A spaceship approaching an asteroid at a speed of 0.60*c* launches a rocket forward with a speed of 0.40*c* relative to the spaceship. At what speed is the rocket approaching the asteroid as measured by an astronaut on the asteroid?
A) 0.81*c* B) 1.0*c* C) 0.76*c* D) 0.64*c* E) 0.96*c*

19) 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 0.78*c*. The commander also observes ship *A*, advancing in the rear, with a relative velocity of 0.31*c*. What is the velocity of ship *C*, relative to an observer on ship *A*?



A) 0.88*c* B) 0.38*c* C) 1.4*c*
D) 0.62*c* E) 1.1*c*

20) Two spaceships are approaching one another, each at a speed of 0.28*c* relative to a stationary observer on Earth. What speed does an observer on one spaceship record for the other approaching spaceship?

21) A spaceship is moving away from the earth with a constant speed of 0.80*c*. The spaceship fires a 28-kg missile with a speed of 0.50*c* relative to the spaceship. What is the speed of the missile measured by observers on the earth if the missile is fired
(a) away from the earth?
(b) toward the earth?

22) A navigational beacon in deep space broadcasts at a radio frequency of 50 MHz. A spaceship approaches the beacon with a relative velocity of 0.40*c*. What is the frequency of the beacon radio signal that is detected on the ship?
A) 55 MHz B) 60 MHz C) 66 MHz
D) 71 MHz E) 76 MHz

Other question areas
Conceptual questions on which measurement of a given property is in the proper frame.
Conceptual questions on reading spacetime diagrams.
Lorentz Invariance.