

Skills 9&10: Measuring space and time

Name _____

#9: Comfortably measure time in meters and distance in seconds.

#10: Calculate the time rate of change of various quantities. Comfortably manipulate formulas which deal with time rates of change.

1. How long does it take light to travel each of the following distances?

- (a) _____ 600 000 km (c) _____ a light year (e) _____ 30 meters
(b) _____ 3 000 m (d) _____ 30 minutes (f) _____ 30 seconds

2. A rocket is traveling at two-thirds the speed of light relative to Lab A. How much time elapses in Lab A as the rocket travels each of the the following distances? The distances are given as measured in Lab A.

- (a) _____ 600 000 km (c) _____ a light year (e) _____ 30 meters
(b) _____ 3 000 m (d) _____ 30 minutes (f) _____ 30 seconds

3. A rocket is traveling at two-thirds the speed of light relative to Lab A. How far does light go as the rocket travels each of the following distances? The distances are given as measured in Lab A.

- (a) _____ 600 000 km (c) _____ a light year (e) _____ 30 meters
(b) _____ 3 000 m (d) _____ 30 minutes (f) _____ 30 seconds

4. A rocket is traveling at two-thirds the speed of light relative to Lab A. How far does the rocket go, as measured in Lab A, during the time it takes light to travel each of the following distances?

- (a) _____ 600 000 km (c) _____ a light year (e) _____ 30 meters
(b) _____ 3 000 m (d) _____ 30 minutes (f) _____ 30 seconds

5. In the Earth frame, San Francisco is about 3500 km from St. Louis and about 4750 km from Washington, DC. For now, let's assume that all three lie along a single straight line. (They are actually pretty well 'lined up,' but we also need to assume the Earth is flat for these questions.)

Answer each of the following by giving measurements observed in the Earth frame:

- (a) _____ How long would it take light to go from San Francisco to St. Louis?
(b) _____ How long would it take light to go from Washington, DC to St. Louis?
(c) _____ How long would it take anything going half light speed to go from San Francisco to St. Louis?
(d) _____ A rocket going $0.8c$ passes San Francisco and then zooms past Washington, DC. How much time elapses?

- (e) A rocket going $0.8c$ passes San Francisco at the same time that a radio signal is sent from San Francisco.
 _____ How far will the rocket have gone by the time the radio signal reaches St. Louis?
 _____ How far will the radio signal have gone by the time the rocket reaches St. Louis?
- (f) A radio signal is sent from San Francisco to St. Louis. At the same moment (as measured in the Earth frame), another radio signal is sent from Washington, DC to St. Louis.
 _____ Which signal arrives in St. Louis first?
 _____ How much time elapses between the arrival of the first signal and the arrival of the second signal?
- (g) One rocket with speed 0.75 passes San Francisco on its way to Washington, DC. At that same moment (as measured in the Earth frame), another rocket with speed 0.75 is passing Washington, DC on its way to San Francisco.
 _____ Which one gets to St. Louis first?
 _____ How much sooner does it get there?
- (h) _____ Is it possible for one rocket to leave San Francisco at the same time as another rocket leaves Washington, DC and yet have both rockets arrive in St. Louis at the same time?
- (i) _____ Is it possible for one radio wave to leave San Francisco at the same time as another radio wave leaves Washington, DC and yet have both signals arrive in St. Louis at the same time?
- (j) What can be deduced if two radio waves arrive in St. Louis at the same time and it is known that one came from San Francisco and the other came from Washington, DC? Quantify your answer.

The Flip Side

6. Write a question for which the answer is “The rocket is going 0.75 times the speed of light.”
7. Write a question for which the answer is “The radio signal arrives 50 m before the rocket.”
8. Write a question which tests the ability of a student to measure distance in units of seconds.

The Answers

1. (a) 600 000 km (c) a light year (e) 30 meters
(b) 3 000 m (d) 30 minutes (f) 30 seconds
2. (a) 900 000 km (c) 1.5 year (e) 45 meters
(b) 4 500 m (d) 45 minutes (f) 45 seconds
3. (a) 900 000 km (c) 1.5 year (e) 45 meters
(b) 4 500 m (d) 45 minutes (f) 45 seconds
4. (a) 400 000 km (c) $\frac{2}{3}$ year (e) 20 meters
(b) 2 000 m (d) 20 minutes (f) 20 seconds
5. (a) 3500 km
(b) 1250 km
(c) 7000 km
(d) 5937.5 km
(e) When the radio signal reaches St. Louis, the rocket will have gone 2800 km. By the time the rocket makes it to St. Louis, the light will have gone 4375 km.
(f) The signal from DC arrives 2250 km before the signal from San Francisco.
(g) The rocket from DC arrives 3000 km before the rocket from San Francisco.
(h) Sure, the rocket from San Francisco just has to go faster. In fact, it must go $\frac{3500}{1250} = 2.8$ times faster.
(i) No! Radio waves always go at light speed.
(j) The signal from San Francisco must have been sent before the one from DC (2250 km before, to be exact).