Skill 8: Clock Synchronization

Name ____________________

#8: Describe effective means for synchronizing clocks for use in measuring time and space.

1. Imagine three clocks all in a line, each 150 000 km apart.

   (a) If a flash of light were emitted from the first clock, how long would it take for that light to get to the second and third clocks?

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   (b) Assuming that the first clock read 0.0000 s when the flash of light was emitted, what should the readings be on the second and third clocks when the light arrives if the clocks are all synchronized.?

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   (c) Assume that all three clocks are synchronized. A firecracker explodes near the first clock when it reads 6.5000 s (Event A).

   i. What would the readings be on the second and third clocks at the moment the firecracker explodes? (Don't make this harder than it is!)

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   ii. What would the readings be on the second and third clocks when observers at those clocks saw the light from Event A?

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   iii. If some Event B occurred near the third clock at the same time as Event A, what would the readings of all the clocks be for Event B?

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   iv. ____________ What would the readings be on the second clock when observers at that clock saw the light from Event B?

   v. An observer in a rocket flies from the first clock past the other two at a rate of $0.5c$. When the rocket passes the first clock, it reads 6.5000 s. What does the second clock read as the rocket passes it? And the third? (*Note:* You are not being asked anything about the time that passes in the rocket.)

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   Bonus: How much time does elapse on the rocket's clocks between passing the first and second clock? The second and third clock? The first and third clock?

   ____________ ____________ ____________

(d) How would the answers to (a) and (b) change if the distances between the clocks were reduced to 150 km?

2. Someone suggests the following scheme for synchronizing three clocks:

   - Stand next to the first clock with a fourth clock and set the fourth clock to the time shown on the first clock.
   - Take the fourth clock to the second clock and set the second clock to the time shown on the fourth clock.
   - Take the fourth clock to the third clock and set the third clock to the time shown on the fourth clock.

   Why does this scheme not result in having all three clocks synchronized?
   Hint: The answer has to do with relativity. What happens when one clock moves relative to another?

3. Draw a diagram which shows how you could lay out a network of 25 clocks on a two-dimensional grid where the grid spacing is 150 km and the clocks cover a square area that is 600 km on each side.

   (a) Label the time it would take light to get from the clock at the center to each of the other clocks.

   (b) Explain how to synchronize all the clocks in the grid, using the central clock as the 'master' clock.

   (c) Explain briefly how to extend this network of clocks to cover a three-dimensional volume.

Bonus: In the three-dimensional case, there would only be three different distances between the central clock and each of the nearest clocks. What are those three distances?

Skill 8: Answers

1. (a) 150 000 km (or 0.5 s) and 300 000 km (or 1.0 s)
   (b) 0.5000 s and 1.0000 s
   (c) i. Both read 6.5000 s
       ii. 7.0000 s and 7.5000 s
       iii. all would read 6.5000 s
       iv. 7.0000 s (Notice that this observer would see the light from both Event A and Event B at the same time – why?)
       v. 7.5000 s and 8.5000 s

   Bonus: 0.8660 s of time passes in the rocket for every 1.0000 s of time that passes in 'the lab.'

   (d) Reducing the clock spacing by a factor of 1000 will reduce the times on the clocks by a factor of 1000. So light takes only 0.0005 s to go from clock to clock.

2. The clock being carried from one place to another will run at a slightly different rate than the stationary clocks, so setting the second and third clocks to the time on the fourth clock will not result in synchronicity.

3. (a) Clocks along the axes are 150 km and 300 km from the central clock. Clocks along the diagonal are 212 km and 424 km from the central clock. The final set of clocks are essentially 'over two and up one' and are 335 km from the central clock.
   (b) Send out a light signal from the central clock. When that signal reaches each of the surrounding clocks, those clocks should set their time to their distance (in seconds) from the central clock.
   (c) Making this three-dimensional just requires putting 'layers' of grids above and below the grid that contains the central clock. The light signal emitted from the central clock will go out in all three dimensions, so the same method of synchronizing the clocks will work.

Bonus: The clocks nearest the central clock would be at the corners of a cube which has 150 km on each side. The distances from one vertex of the cube to the others are all either 150 km, 212 km, or 260 km.