**The Story:**

Deep in outer space two caravans of rockets pass each other traveling in opposite directions at identical speeds. One caravan consist of red ships; the other, blue. Each ship is stamped with a serial number. The ships are otherwise identical to one another. Each ship has a window on either side which lets it photograph what is directly next to it (but does not let the people inside look forward or backward). Each ship has a clock inside. The clocks aren’t synchronized in either caravan, *but the caravans do not know this* – each thinks its own clocks are synchronized. The ships within the caravans can take pictures of each other as they pass by. (See figure.) The ships within a caravan cannot communicate with one another, but when the caravans arrive at their respective destinations, the ships within each caravan pool their photos and analyze them. These photos show passing ships’ serial numbers and clock readings as well as the clock reading of the ship taking the photo.

#2

0:10

#5

**Figure:** An alien in blue ship 2 and red ship 5 take photos of one another when they pass. The photo by blue shows red’s serial number and what the clock in red reads (0:35). It also bears a time stamp that marks blue’s clock reading (0:10) when the photo was taken.

0:35

You can control a simulation of this situation with the up and down arrows. If you double click on a red rocket when it is aligned with a blue rocket, a photo is taken and stored in the bottom corner of the simulation. Up to two photos can be displayed at a time. With pairs of photos you can deduce what Red will claim about Blue based on the measurements Red takes.

1. Produce two photos that you would say were taken at the same time in the simulation. Show them below. Which photo does Red claim was taken first? Which photo does Blue claim was taken first?
2. After examining its photo collection, Red claims Blue’s clocks run more slowly than Red’s and that Blue’s clock’s are not synchronized with one another. Produce a pair of photos that Red would use to determine how much slower a given blue clock runs. Copy your photos below. Based on these photos what does Red conclude about the ratio of Blue’s clocks’ rate compared to Red’s? Check that another pair would produce the same conclusion.
3. However, Blue concludes that the Red clocks run slower than the blue clocks. Produce a pair of photos that Blue would use to determine how a Red clock runs compared to Blue. Copy your photos below.
4. Red also concludes that the spacing between blue ships is different than the spacing between red ships. It does this by looking at two photos that it thinks were taken at the same time. Produce a pair of photos that would let Red calculate the ratio of the spacing between blue ships compared to the spacing between red ships.[[1]](#footnote-1) What does Red calculate for this ratio? Check with a second set of measurements that it produces the same result.
5. Based on your previous measurement you can also figure out how much Red thinks Blue’s clock times shift per blue ship. What is this value? Is it the same as the time shift per rocket we see on the screen?
6. If you right-click the mouse you will produce two meteors next to red rocket 5 traveling in opposite directions. Which meteor does Red think is moving faster? Which meteor does blue think is moving faster? How do the speeds measured by Red and Blue compare? In the space below record both your answer and the observations used to support it.
7. Line up Red 5 and Blue 5, then emit a pair of meteors. Run time forward a bit to search for moments when the meteor lines up with pairs of colored rockets and their time readings are nice numbers.
8. Record pictures below of the rocket pairs and meteors of when you think the left meteor and right meteor simultaneously have this arrangement.
9. Record pictures below of the rocket pairs and meteors of when Red thinks the left meteor and right meteor simultaneously have this arrangement.
10. Record pictures below of the rocket pairs and meteors of when Blue thinks the left meteor and right meteor simultaneously have this arrangement.

1. Choose two red ships that are four ships apart. If you pick ships closer than this one will not be lined up with a blue ship when it reads the same time as the other. [↑](#footnote-ref-1)