Course and Section_______ Names ___________________________

Date___________________ ___________________________

SPECIAL RELATIVITY SIMULATION

Introduction

In this online simulation you will further explore the odd behavior of quantities moving close to the speed of light using the theory of special relativity.

Input all answers in Blackboard.

1 – Preliminary Questions

Suppose Bob is on a train. He stands half way between the front and back of train holding two baseballs, one in each hand. The train is at rest. He throws each ball with the same speed but in opposite directions. The baseballs hit the opposite ends of the train.

According to Newton mechanics:
1. As observed by Bob, do the balls reach each end at the same time?

Bob repeats the experiment as the train moves at a constant speed with respect to Alice who sits in the train station.
2. As observed by Bob, do the balls hit each end at the same time?
3. As observed by Bob, do the balls have the same speed?
4. As observed by Alice, do the balls hit each end at the same time?
5. As observed by Alice, do the balls have the same speed?
6. Do Bob and Alice agree on the time each ball hits the opposite end of the train?

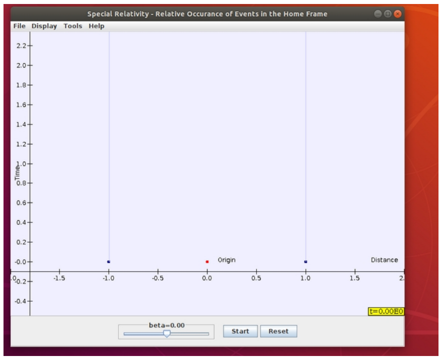
Now, instead of the baseballs Bob uses two lasers aimed in opposite directions. The train moves at a constant speed with respect to Alice who sits in the train station.
According to Special Relativity:
7. As observed by Alice, do the laser beams have the same speed?
8. Is your answer to question 7 in agreement with the answer to question 5?
9. Do Bob and Alice agree on the time each beam of light hits the opposite end of the train?

Calculate the relativistic factor $\gamma(v)$ of the following speeds (use $c = 3.0 \times 10^8$ m/s)

10. v = 0 mi/hour
11. v = 350,000 mi/hour (carefully calculate)
12. v = 186,250 mi/s
13. $v = c$

2 – Simultaneity

Open the simulation (https://pages.physics.ua.edu/lab10x/2em/SIM/applet/sr_simultaneous.jar)



The graph displays the plot of t vs x. The two vertical blue lines represent the front and rear end of a single wagon train. A bulb is located halfway between the two ends. When the animation starts light is emitted and it travels toward each end. You can select the train velocity using the relativistic parameter $\beta = v/c$. The simulation runs according to special relativity, not Newtonian mechanics. Clicking in the region show a small yellow box at the bottom left of the screen which displays the spacetime coordinates. The simulation runs in dimensionless units when the speed of light is set to c=1. Set v = 0 c, i.e. β = 0 and run the animation

14. Do the two beams reach each end at the same time?

Set v = 0.2 c and run the animation
15. Do the two beams reach each end at the same time?
16. What is the time difference between the two events?

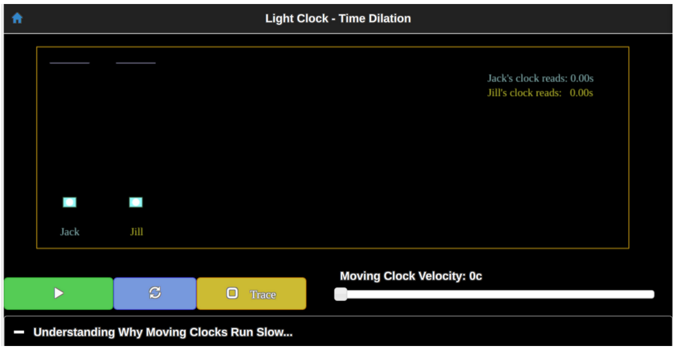
Set v = 0.6 c and run the animation
17. Do the two beams reach each end at the same time?
18. What is the time difference between the two events?

19. How does the time difference at v =0 .2 c compare to v = 0.6 c ?

An event is an occurrence in space and time. For example, the light ray striking the left or right end of the wagon train in the simulation constitutes an event.
20. What has the above simulation demonstrated?

3 – Time Dilatation

Open the simulation (https://galileoandeinstein.phys.virginia.edu/more_stuff/Applets/Lightclock/home.html)



The simulation shows Jack and Jill and the time as measured by each one of their clocks. When you run the simulation a photon is emitted from a the box at the bottom, bounces off a mirror and returns into the box. Run the simulation with the moving clock velocity $v = 0\ c$.
21. Do both clocks show the same time elapsed?

Set the clock $v = 0.5\ c$ and run the simulation.
22. What time does Jack's clock read?
23. What time does Jill's clock read?

When the simulation stops, Jill observes her photon her photon has returned to the box at the same point where it started.
24. Has Jack's photon already made it back to his box?
25. As observed by Jack, how long does it take Jill's photon to return to where it started?
26. As observed by Jack, how long does it take for his photon to return to where it started?
27. Using the equation for time dilation what is the gamma factor in this case?
28. Does it take the same amount of time for each photon, as measured by each observer, to return to its own initial point?

29. As observed by Jack, how does the distance traveled by Jill's photon compare to the distance traveled by his photon?
30. As observed by Jill, how does the distance traveled by Jack's photon compare to the distance traveled by her photon?
31. As observed by Jill, how long does it take for Jack's photon to return to where it started?

Set the clock $v = 0.8\ c$ and run the simulation.
32. What time does Jack's clock read?
33. What time does Jill's clock read?
34. Using the equation for time dilation what is the gamma factor in this case?

35. Is there any speed you can find where Jill's clock runs faster than Jack's clock?