Adding Velocities

**Part A: Galilean Relativity**

1. Imagine Alice is walking along a platform of length *L* with two clocks, one at each end. Bob is sitting on the ground beside the platform. The platform is moving at *v* meters per second relative to the ground and Bob. Alice is walking along the platform at *u* meters per second relative to the platform. According to Galileo’s relativity principle, at what speed is Alice moving relative to Bob?
2. According to Einstein why would this be incorrect?

**Part B: Einstein’s Relativity**

1. Let’s assume that according to Alice the clocks on the platform are synchronized. She sets off from the back of the platform when the clocks read zero. What time do the clocks read when she is done traversing the platform and has arrived at the second clock?
2. Based on what we learned in the previous exercise on clock synchronization, will Bob agree that the clocks on the train are synchronized? By how much will two synchronized clocks be out of synchronization in a frame in which they are moving at *v* along a line joining them and in which they are *L* apart?
3. If Bob compares his clock to that of Alice he will find that her clock is running slow due to time dilation. By what factor will he find her clock to run slow?
4. Based on your answers to a-c, how long does Alice’s walk take on Bob’s clock?
5. According to Bob how far does Alice walk relative to the ground?
6. Using your answers in d and e, what is Alice’s speed relative to the ground?

**Part C: Comparisons**

1. Let’s suppose Alice’s platform is moving at 20 m/s and that Alice’s walking speed is 1 m/s relative to the platform. How fast is Alice walking relative to Bob? How does this result compare to that determined using Galilean relativity?
2. Suppose Alice is on a spaceship equipped with a series of one-shot rockets, each of which can accelerate the ship to *c/2* from rest. Alice fires one rocket to leave the solar system (ignore gravity here) and is then traveling at *c/2* (relative to Bob on Earth) in deep space. She now fires a second rocket, keeping the same direction. How fast is Alice moving relative to Bob? She now fires a third rocket, keeping the same direction. Find her new speed. Can you draw any general conclusions from your results?

**Putting It All Together**

Review the work that you have done as a group and discuss any points that need clarification.

Summarize the concepts in your notebook. Be sure to address the following points:

- Summarize Galileo’s and Einstein’s approach to adding velocities. In what cases are they equivalent?

- Is it possible to accelerate an object faster than the speed of light?

- What if Alice walked across the width of the train? What would be the same? What would be different?