1. World lines [20 pts.]

*Draw the space-time diagrams for the following cases, always in the frame of reference of the observer. The observer starts at the origin of coordinates.*

A. An object that is not moving.

B. An object moving toward the right of the diagram at 10 m/s, as seen by an observer moving in the same direction at 10 m/s.

C. A decelerating object thrown by the observer.

D. A car that is slowing down as it approaches the observer.

E. The motion of a pendulum.

2. Laser tag and the Minkowskis [20 pts.]

The Minkowski twins, Archie and Betty, are playing a game of laser tag. Draw the space-time diagram for the game, with the world lines corresponding to the players and the light pulse, in the following situations. Remember that light moves on 45 deg lines on a diagram, but exaggerate the likely speeds of the human participants so that we can see their effects on the diagram.

A. Archie runs toward the right at constant speed and fires his laser gun toward Betty who’s standing still on the left. Betty is not defenseless. She’s is holding a mirror, so the laser pulse bounces back to Archie and hits him.

B. Betty is running toward Archie on the left, who’s dodging left and right trying to avoid being hit (despite the fact that dodging in a universe with only one spatial dimension is pretty useless). When Archie sees that Betty is ready to fire, he stops to use his mirror. However, it is too late for him. This time Betty is equipped with a tachyon tag gun of faster-than-light particles that she got at a nearby Star Trek shop. Show the tachyon pulse with a dashed line. What is the slope of something “faster than light” in a space-time diagram?
3. Only a theory [30 pts.]

A. Are Relativity and Newtonian mechanics incompatible? Under which circumstances would you prefer one over the other?

B. Sometimes people use the expression “it’s just a theory” in a critical manner to mean that arguments will change as time passes, and often that all arguments are equivalent (and equally unsuitable and/or not worth of consideration). What would you answer to the skeptical comment that Newtonian mechanics, Special Relativity, and General Relativity are “just theories”? Please, develop your thoughts and write at least a few lines on this topic.

C. Similarly skeptical (and uninformed) people often ask “what use is a theory?” Can you point out your favorite consequence of Newtonian mechanics? One dramatic consequence of Special Relativity’s equivalence of mass and energy? One everyday use of General Relativity?

4. Star Trek and Special Relativity [30 pts.]

It is a day like any other at the helm of the Federation vessel USS Enterprise. The Enterprise is moving at 30% of the speed of light away from a Borg Collective cube, when Captain Picard orders to launch forward a proton torpedo that moves at 80% of the speed of light with respect to the Enterprise (Don’t ask me why. I’m sure he has a trick up his sleeve).

A. At what fraction of the speed of light is the torpedo moving in the Borg’s battleship frame? (Hint: Recall the version of the velocity addition law that applies in Relativity)

B. What if Picard shoots the torpedo toward the Borg cube instead of forward? How fast does it move in the Borg’s frame (as a fraction of the speed of light)?

C. How much slower are the Enterprise clocks running as seen by a Borg observer? Imagine a video-link conversation between the Borg Queen and Picard. Do you think it will sound natural? Imagine Picard starts singing and hits an G#5 note, of frequency 784 Hz. What frequency will the Borg hear? (Mercifully, Star Trek uses faster-than-light tachyon links.) (Hint: remember the gamma factor $\gamma=1/\sqrt{1-v^2/c^2}$)

Tell me how things are going so far

1. Are the lectures interesting and understandable?
2. Are the homeworks helping better understand the material?
3. How do you like the book? Have you used it or do you rely mostly on the notes?
4. Have we covered something that you found particularly interesting?
5. Did I miss (or did not properly develop) an interesting topic?
6. Overall, is the course challenging you? Do you like it?