**PHYSICS 420 (Spring 2006)**
**Dennis Papadopoulos**

**Homework # 4**
**DUE TUESDAY, 2/28/06**

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**PROBLEMS**

1. Construct a space-time diagram that involves a stationary observer (x, ct) and an observer (x′, ct′) moving with $\gamma = 3$. The word line of a photon in this diagram is at a 45° degree angle with respect to the x and ct axes.
   a) If the units of time are seconds what are the units of the space axis in this diagram.
   b) What is the value of the angle $\theta$ (in degrees) that the ct′ axis makes with the ct axis.
   c) What is the value of the angle that the axis x′ makes with the world line of a photon.
   d) Show the word line of a stationary observer in its own frame.
   e) Consider an event with coordinates (x = 0, ct = 1) and draw the plane of simultaneity for this event.
   f) What coordinates (x′, ct′) correspond to the (x = 0, ct = 1) event.
   g) Draw the wordline of an observer that leaves the origin in a rocket with $\gamma = 3$, travels till ct = 2 and returns to the origin with $\gamma = 6$.
   h) What is the angle between the returning world line and the ct axis.
   i) What is the length of time in the stationary ($\Delta t$ and moving ($\Delta t'$) frame for that duration of the round trip in question (g). (Ignore Doppler shifts).

2. Assume that you are at the origin of a laboratory reference system at time t = 0 when you start your clock (event A). Determine whether the following events are within the future lightcone or past lightcone of event A, or elsewhere.
   a) A flashbulb goes off 7 m away at time t = 0.
   b) A flashbulb goes off 7 m away at time t = 2 s.
   c) A flashbulb goes off 70 km away at time t = 2 s.
   d) A flashbulb goes off 700,000 km away at time t = 2 s.
   e) A supernova explodes 180,000 ly away at time $t = -5.7 \times 10^{12}$ s.
   f) A supernova explodes 180,000 ly away at time $t = 5.7 \times 10^{12}$ s.
   g) A supernova explodes 180,000 ly away at time $t = -5.6 \times 10^{12}$ s.
   h) A supernova explodes 180,000 ly away at time $t = 5.6 \times 10^{12}$ s.

   For items (e) and (g), could an observer in another reference frame moving relative to yours measure that the supernova exploded *after* event A? For items (f) and (h), could an observer in another frame measure that the supernova exploded *before* event A?

3. $\tau$ Ceti is the closest single star that is similar to the Sun. At time t = 0, Alice leaves Earth in her starship and travels at a speed of 0.95c to $\tau$ Ceti, 11.7 ly away as measured by astronomers on Earth. Her twin brother, Bob, remains at home, at x = 0.
   i) According to Bob, what is the interval between Alice's leaving Earth and arriving at $\tau$ Ceti?
   j) According to Alice, what is the interval between her leaving Earth and arriving at $\tau$ Ceti?
   k) Upon arriving at $\tau$ Ceti, Alice immediately turns around and returns to Earth at a speed of 0.95c. (Assume that the actual turnaround takes negligible time.) What was the proper time for Alice during her round trip to $\tau$ Ceti?
   l) When she and Bob meet on her return to Earth, how much younger will Alice be than her brother.

4. Serway problem 2.20.

5. Serway problem 2.29.