Electromagnetism (PHYS 295): Guide 6

Intro:

Over this mid-term week we have been starting to explore special relativity. This week we will continue with the invariant interval and energy-momentum.

Soon we will transition back to Purcell and Morin with Chapter 5 which starts our study of magnetic fields. But this will be after break.

Reading:

- PM Appendix G
- Sing out if you wish to have an additional resource on special relativity

A look ahead:

- Chapter 5 of PM

Problems: Due Friday March 8 before class

(1) 4.29

(2) 4.38 Assume these light bulbs are the old kind and behave like resistors.

(3) (2 pts.) A super-fast WorldStar train moves uniformly during a thunderstorm. Lighting bolts strike the front and back of the train, leaving char marks on the ground. Sophie is a dedicated trainspotter, in macintosh, standing directly next to the tracks on the embankment watching the train pass. She sees both flashes of light from the lighting strikes in the same instant. Theodore is half-way down the car looking out of the window at the storm. He sees Sophie as she passes by and the two flashes of light at the same moment.

  (a) Sketch the situation in Sophie's reference frame, just as the light flashes reach Sophie. Include the light fronts, Sophie, the char marks on the ground, and the train. Indicate the direction of motion of the train with an arrow.

  (b) Again in Sophie's reference frame, sketch the situation shortly after the lighting strikes. This is *before* your previous picture. Please include the light fronts, Sophie, the char marks on the ground, Theodore, and the train.

  (c) Now switch to Theodore's reference frame, and sketch the situation just as the light flashes reach Theodore, i.e. repeat part (a) in Theodore's frame. Please be sure include the direction of Sophie's motion.

  (d) In Theodore's reference frame, sketch the situation shortly after the lighting has struck both ends of the train. This is the analog to part (b) in Theodore's frame. Include the light fronts, Sophie (with direction arrow), the char marks (with direction arrows), and the train.

  (e) Describe in words the order of the events of the lighting strikes and observations of the flashes of light according to Sophie.

  (f) Describe in words the order of the events of the lighting strikes and observations of the flashes of light according to Theodore.

Hint: Recall that all observers must agree on the existence of events. For instance if two flashes of light reach an observer at the same moment - defining an event - then all observers will agree that this particular event occurred, as defined by the arrival of the flashed of light at the observer. However, all observers do not have to agree on the *order* of distant events.

(4) Suppose a 'mind reader' in London claims to know what his twin brother in New Zealand says at any moment, within less than one-hundredth of a second after a word is uttered. Is there anything extraordinary about this claim? Defend you answer with a calculation.

(5) *Space-time diagrams* Harold captains a rocket moving at $v = \frac{1}{2}c$ in the $+x$ direction relative to Maud, who is on Mars. Their positions coincide at $t = 0$.
   (a) Plot the worldlines of Harold and Maud in a (t, x) space-time diagram, in Maud's frame.
   (b) The rocket emits light in the forward and backward directions at $t = 2s$. Add the light fronts to the diagram.
   (c) Maud signals to the rocket at $t = 1s$. What is the earliest time she can expect a reply?

(6) In the classic 'pole in barn' paradox or 'ladder in barn', the ladder approaches a barn at high speed. Let the speed of the runner be 0.866 in the barn's frame. Please assume that the proper lengths of both the ladder and the barn are 5 m.
   (a) What is the length of the ladder in the barn's frame? What is the length of the barn in the ladder's frame?
   (b) The runner with the ladder arranges things so that the ladder comes to a stop when the front of the ladder reaches the back of the barn. This is done in the proper frame of the runner. Does the ladder fit in the barn at any time?
   (c) Describe the sequence of events in the barn's frame.