Physics 323, Spring Quarter 2015
Electrodynamics: Homework Assignment 9

Turn in all problems and clearly note all constants and assumptions you use. (1-point penalty each otherwise)

Due 9:00 am Thursday June 4

1. Transformation of force.

a. Show that by transforming the numerator and denominator between different frames, you get Griffith's equations 12.65 & 12.66. (Basically, just go through Griffith's derivation). And thereby demonstrate you recover the special case of Griffith's 12.67 when the particle is at rest in the initial frame.

b. Consider a charged-particle beam moving at speed v as seen in the laboratory. In the laboratory frame, the beam consists of a uniform cylinder of charge density ρ, with q the charge of each particle in the beam. What force does the laboratory observer see on a charge a distance d from the beam axis? You could have noticed that the charge density and current form a 4-vector (called the 4-current), then transform this 4-current to the rest frame of the beam, then find the (purely electrostatic) fields. Then transform the fields back to the laboratory frame to find the Lorentz force from the laboratory fields. Whew. You may find it simpler to again use the 4-vector nature of the 4-current to find the charge density in the charge's rest frame (there's no current in this frame). This charge-density transformation is very simple, it's just inverting Lorentz contraction along the beam axis direction. Then you can easily find the E-field in the charge's rest frame (there's no B-field). Then you can use the result of (a) to transform the force directly.

2. Consider the charged-particle beam in problem 1b. In all space (inside and outside the beam), find in the laboratory frame:
a. The **E** and **B** fields.
b. The energy density and momentum density. Griffiths equations 8.5 and 8.29 remain relativistically correct in the frame where fields are measured.

3. Relativistic Doppler shift. Consider a source of very short-duration electromagnetic pulses (e.g., a radar antenna) at rest at the origin of reference frame S. An observer moves in the x-direction at velocity v as seen in frame S. The observer is at rest in frame S'. Suppose a first pulse is sent at t=0 when the observer is at position $x=x_0$. Further suppose the (n+1)th pulse is sent out at $t=n\tau$, where τ is the period.
a. Carefully draw the Minkowski diagram (space-time diagram) for frame S identifying the two events representing the arrival of the first and (n+1)th pulse at the observer.
b. Find the time interval between those two pulses in the observer's frame S'.
c. And therefore find the frequency υ' in the observer's frame in terms of the source frequency υ and the observer's velocity factor β. This is the relativistic Doppler shift.
d. Briefly discuss how this might be applied to the receding-laser problem (#4) in problem set 8.

4. Consider the copper wire we discussed in class carrying 10 Amperes of electron current and where the copper ions are not moving. Suppose the wire had cross-section 1mm^2 and there's one conduction electron per copper atom.
a. With the current off, estimate the number of conduction electrons per cm^3. You'll need physical constants of copper for this.
b. Now apply the 10 Ampere current. In a time Δt, how many electrons pass a certain position along the wire in that time? Find this time in two ways: (i) from the number of conduction electrons, and (ii) from the current.
c. What is the approximate drift speed of the conduction electrons?

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