PHY102 : Assignment 6

1. (P&M Example) Fixed in the frame F is a sheet of charge, of uniform surface density σ, that bisects the dihedral angle formed by the xy and the yz planes. The electric field of this stationary sheet is of course perpendicular to the sheet. How will this setup be described by observers in a frame F' that is moving in the x direction with velocity $0.6c$ with respect to F? That is, what is the surface charge density σ', and what are the strength and direction of the electric field in F'? Find the component of the field perpendicular to the sheet in F', and verify that Gauss's law still holds.

2. (P&M 5.1) On a nylon filament 0.01 cm in diameter and 4 cm long there are 5×10^8 extra electrons distributed uniformly over the surface. What is the electric field strength at the surface of the filament :

   (a) In the rest frame of the filament ?

   (b) In a frame in which the filament is moving at a speed 0.9c in a direction parallel to its length ?

3. (P&M 5.13) A stationary proton is located on the z axis at $z = a$. A negative muon is moving with speed $0.8c$ along the x axis. Consider the total electric field of these two particles, in this frame, at the time when the muon passes through the origin. What are the values at that instant of E_x and E_z at the point $(a, 0, 0)$ on the x axis?

4. (P&M 5.25) Consider the trajectory of a charged particle which is moving with speed 0.8c in the x direction when it enters a large region in which there is a uniform electric field in the y direction. Show that the x velocity of the particle must actually decrease. What about the x component of momentum?

5. (P&M Example) Two protons are moving parallel to one another a distance r apart, with the same velocity βc in the lab frame. At the instantaneous position of one of the protons the electric field strength caused by the other as measured in the lab frame is $\gamma e/4\pi\epsilon_0 r^2$. But the force on the proton measured in the lab frame is not the same. Verify this by finding the force in the proton rest frame and transforming that force back to the lab frame. Show that the discrepancy can be accounted for if there is a magnetic field β times as strong as the electric field, accompanying this proton as it travels through the lab frame.

6. (P&M 5.30) Consider a composite line charge consisting of several kinds of carriers, each with its own velocity. For one kind, k, the linear density of charge measured in frame F is λ_k and the velocity is $\beta_k c$ parallel to the line. The contribution of these carriers to the current in F is then $I_k = \lambda_k \beta_k c$. How much do these k-type carriers contribute to the charge and current in a frame F' which is moving parallel to the line at velocity $-\beta c$ with respect to F ? By following the steps we took in the transformation in Fig. 5.20, you should be able to show that

$$\lambda'_k = \gamma \left(\lambda_k + \frac{\beta I_k}{c} \right) \qquad I'_k = \gamma(I_k + \beta c \lambda_k)$$

   If each component of the linear charge density and current transforms in this way, then so must the total λ and I :

$$\lambda' = \gamma \left(\lambda + \frac{\beta I}{c} \right) \qquad I' = \gamma(I + \beta c \lambda).$$