

## PHY102: Quiz 1

1. A spherical charge distribution has a density  $\rho$  that is constant from  $r = 0$  out to  $r = R$  and is zero beyond. What is the electric field for all values of  $r$ , both less than and greater than  $R$ ? [2.5]

- First, let us look back at the calculation of the force in frames  $F$  &  $F'$ .

We first considered the body to be initially at rest i.e. momentum  $p = 0$  at  $t = 0$ . This is in the

$F$  frame which we will call the "rest frame".

It is confusing a bit since a force acts on the body causing it to accelerate — therefore, the body is not going to be at rest for  $t > 0$ !

Anyway, with a force acting in the  $x$ -direction, we showed that, in the "lab frame"  $F'$  (an observer in this frame sees the "rest frame" moving with velocity  $v$ ), the force

components  $F_x$  &  $F'_x$  to frames' relative motion are given as,

$$F'_x = F_x \quad \& \quad F'_y = \frac{F_y}{\gamma}$$

$\therefore$  The component of force  $F'_x$  to the frames' relative motion in the lab frame is smaller by  $\frac{1}{\gamma}$  than that in the rest frame.

2. Designate the corners of a square,  $l$  on a side, in clockwise order,  $A, B, C, D$ . Put charges  $2q$  at  $A$  and  $-3q$  at  $B$ . Determine the value of the line integral of  $\mathbf{E}$ , from point  $C$  to point  $D$ . (No actual integration needed!) What is the numerical answer if  $q = 10^{-9} \text{C}$  and  $l = 5 \text{cm}$ ? [2.5]

- Now look at the problem we discussed today in the class.

We had 2 sheets of charge densities  $+\sigma$  and  $-\sigma$ . In the frame  $F$ , the sheets are stationary. We determined the electric field in the frame  $F'$  which moves towards left w.r.t.  $F$  with velocity  $\vec{v}$ . We found,

$$E'_z = \gamma E_z$$

Does this contradict with the force relations we derived, knowing that charge is relativistically invariant?

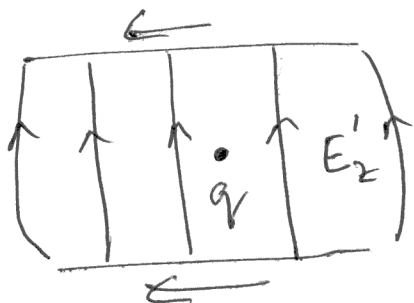
The answer is "absolutely not".

To see this, note that in order to calculate the force, given the electric field, we have to bring in a test charge,  $q$ . To find the force ~~on~~  $q$  in  $F'$ , we will be moving with the particle. In this "particle frame" the particle will be, at least momentarily, at rest. The sheets with the charged densities

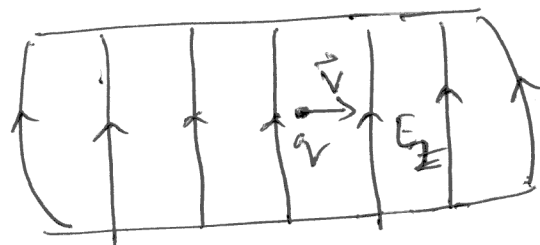
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$\sigma$  &  $\sigma'$  are moving.  $F$  is now the "lab frame" where the charge  $q$  is moving with velocity  $\vec{v}$ .



"Particle frame  $F'$ "



"Lab frame  $F$ ".

(Note that the plates are deliberately shrunk in  $F'$  to remind length contraction.)

$$\therefore E'_z = \gamma E_z \quad \Rightarrow \quad F'_z = \frac{dp_z}{dt} = \frac{1}{\gamma} \frac{dp'_z}{dt'} = \frac{1}{\gamma} F'_z$$

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