

## Hints to Assignment #7 -- 8.022

### [1] Transforming velocities

This is a direct application of the transformation of velocities from a moving frame to the lab frame. Express the velocity in terms of its components and apply the formulas we derived in class. If there are any doubts remaining, lecture notes could be of help.

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### [2] Speed of Light

Show that after  $N$  carts  $u_N < c$  as seen by the lab observer and that this is true for any value of  $N$ . Express  $u_{(N+1)}$  in terms of  $u_N$ , it helps.

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### [3] Lorentz invariants

Use the expressions transforming the 4-position (i.e.,  $t, x, y, z$ ) and 4-momentum ( $E, p_x, p_y, p_z$ ) from a moving frame to the lab one. Substitute in the expression for  $\Phi$ .

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### [4] High energy protons

These are the bread and butter calculations of high energy physicists! Here are a few items to keep in mind:

- The Tevatron brings the protons to a kinetic energy of 1 TeV. If relativity wasn't there, classical theory would have predicted a velocity  $\beta = \sqrt{2 \times 1000/1} = 45!$
  - As we derived in class, Kinetic Energy  $T = \text{relativistic energy} - \text{rest energy}$ . But relativistic energy  $E = \gamma \times \text{rest mass energy}$ . We know the rest mass of the proton and its kinetic energy, thus  $\gamma$  should be pretty straightforward.
  - Check out Fermilab's web page and given link- it's fun! The energy given in that page is for proton before entering the Tevatron.
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### [5] Relativistic collisions

- Introduce your two preferred symbols for the mass and velocity of the compound system that do not overlap with symbols already used in the problem description.
  - Express the initial/final momenta/energies. Conservation can lead you to two equations.
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## [6] Relativistic capacitor

The key element here is that the electric charge is a Lorentz invariant, i.e., the same for all inertial observers. All such observers applying Gauss's law on a closed surface that encloses ALL charges (by measuring the field and areas at the same time in their frame) will find the flux equal to  $4\pi Q$ .

- The applied potential over the two plates fixes the electric field in between the plates (assume the battery is disconnected shortly after charge up).
- There are four relevant equations:  $E=V/d$ ,  $E=4\pi\sigma$ ,  $\sigma=Q/A$ ,  $A = \text{width} \times \text{depth}$
- Pick your system of units, namely CGS.  $1e=4.8 \times 10^{-10} \text{esu}$ .
- In the West-East motion the velocity is parallel to the plates, thus one of the dimensions of the plates contracts- you have a new  $A, \sigma$ , and thus  $E$ .
- In the upward motion the velocity is perpendicular to the plates, thus the dimensions of the plates are the same. Only the spacing between the two plates contracts. Does this matter for  $E$ ?
- Ask yourself how a South-North motion would fit in any of the above two.