PHY 554. Homework 1.

Handed: August 27 Return by: September 10
Bring solution to class or -better- email solutions to vladimir.litvinenko@stonybrook.edu

HW 1.1 (3 points): Find available energy (so called C.M. energy) for a head-on collision in these scenarios:

(a) In CEBAF, polarized 12 GeV electrons collide with protons at rest ;
(b) In one of scenarios for future collides, CERN consider collide 50 TeV protons with 180 GeV electrons;

The rest energy of proton is 938.257 MeV, and rest energy of electron is 0.511 MeV.

HW 1.2 (2 points): Let's consider a futuristic case that humanity decided – and figured out how - to build a storage ring surrounding the equator, i.e. with circumference of 40,075 km.

(a) 1 point: If bending dipole magnets fill 75% of the ring circumference, and we used dipole magnetic field of 8.3 T, demonstrated in LHC, what would be energy of the circulating protons?
(b) 1 point: What magnetic field would be needed if storage ring with the same energy of the ring should fit at Earth largest continent of Asia. Asia could fit a ring with radius of 2,500 km. Assume 75% filling factor.

P.S. USA can fit ring with radius of 1.465 km.

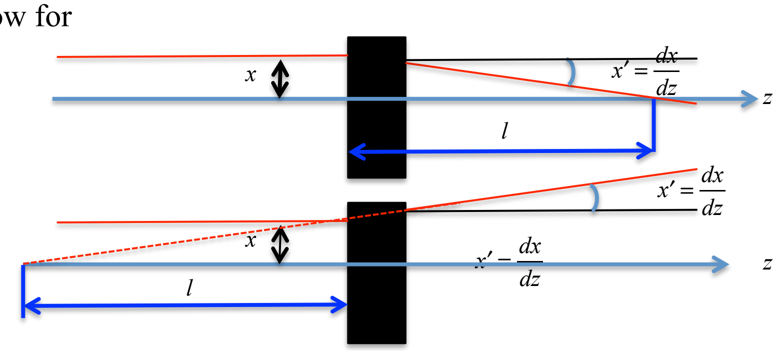
HW 1.3 (2 points): For a classical microtron with orbit factor k=1 and energy gain per pass of 1.022 MeV and operational RF frequency 3 GHz (3 x 10^9 Hz) find required magnetic field. What will be radius of first orbit in this microtron?

Hint: Note that rest energy of electron with $\gamma=1$ is 0.511 MeV. This is energy gain per pass will define available n numbers in eq. (2.6)

HW 1.4 (8 point): Let's first determine an effective focal length, *F*, of a paraxial (e.g. small angles!) focusing object (a black-box) as ratio between a parallel displacement of trajectory at its entrance to corresponding change of the angle at its exit (see figure below):

$$F = -\frac{x}{x'}; x' \equiv \frac{dx}{dz}$$

see figure below for



Let consider a triplet of thin lenses: horizontal focusing (*F*) and defocusing (*D*) lenses with centers are separated by distance L as in Fig. 1. Since quadrupole focusing is opposite for horizontal and vertical directions, the lattice - in accelerator lingo it is magnetic structure – looks like (a) in horizontal direction and (b) in vertical direction. Let's assume that that in Fig 1(a) Q_1 are focusing lenses in horizontal plane with focal length of $\mathbf{F=+1/q_1}$ and, naturally, they are defocusing in vertical direction, Fig 1 (b), with focal length of $\mathbf{F=-1/q_1}$. Similarly, Q_2 is defocusing in horizontal plane (Fig 1(a)) with focal length of $\mathbf{F=-1/q_2}$ and is focusing in vertical plane with focal length of $\mathbf{F=+1/q_2}$.

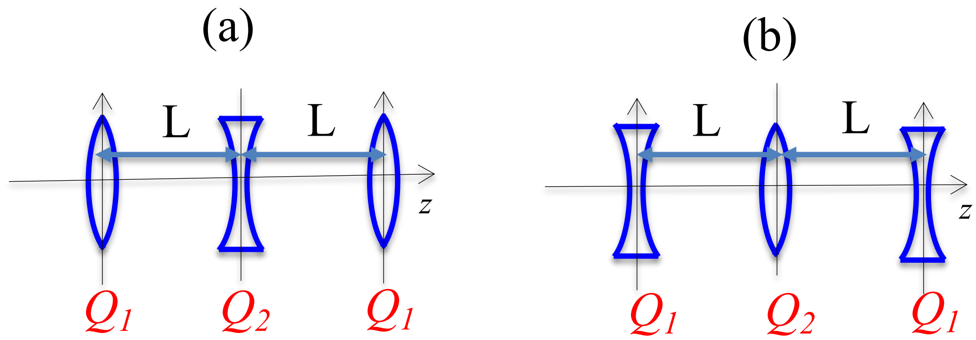


Fig.1. Triplet of short quadrupole lenses: (a) in horizontal direction FDF and (b) in vertical direction DFD.

1. (5 points) Find of horizonal (*FDF)* and vertical (*DFD)* focal lengths of the triplet.
2. (3 points) Write equations connecting $\mathbf{q_1}$, $\mathbf{q_2}$ and **L** when horizontal and vertical focal lengths are equal, for example form of $F_a(\mathbf{q_1,q_2,L})= F_b(\mathbf{q_1,q_2,L})$. If you manage to solve this equation (using Mathematica is fine), I'll doble you points

P.S. Definition (picture) of thin lens: