PHY 554. Homework 1.

Handed: August 28 Return by: September 11
Bring solution to class or send 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 CERN, SPS produced 160 GeV muons collide with protons at rest (the rest energy of proton is 0.938257 GeV, and rest energy of muons is 0.057 GeV);
(b) Super-KEKB collides 7 GeV electrons with 4 GeV positions (the rest energy of electrons and positrons is 0.511 MeV);

HW 1.2 (2 points): Future circular collider at CERN plans to initially collide 180 GeV electron and position beam and later 50 TeV protons beam circulating in storage ring with 100 km circumference.

(a) 1 point: Assuming that bending magnets fill 70% of the ring circumference, what will be bending radius in the magnets? What magnetic field is required to circulate 50 TeV proton beam?
(b) 1 point: What magnetic field is required to turn 180 GeV electrons and postions with the same radius?

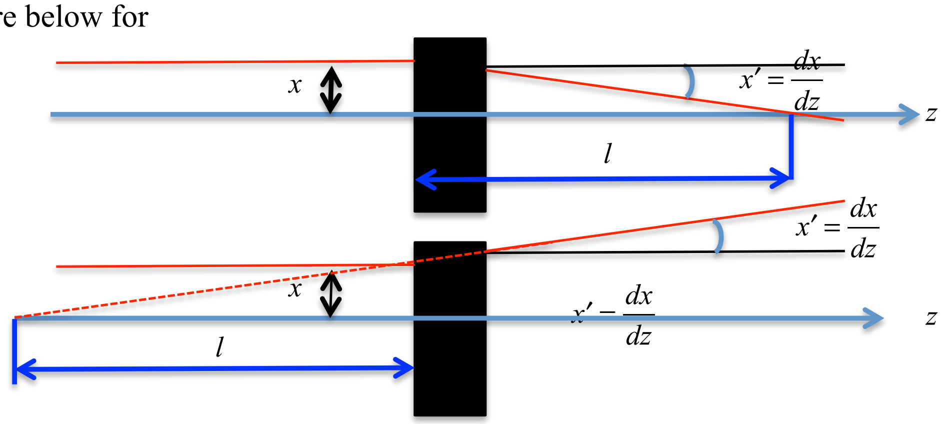
HW 1.3 (2 points): For a classical microtron with orbit factor k=1 and energy gain per pass of 0.511 MeV and operational RF frequency 3 GHz (3 x 10^9 Hz) find required magnetic field. What will be radius of first orbit in this microtron?

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

HW 1.4 (5 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 doublet of two thin lenses: a focusing (*F*) and defocusing (*D*) lenses center separated by distance L as in Fig. 1. The lenses have opposite in sign but not equal focal lengths: f_1 for F and f_2 for D lenses.

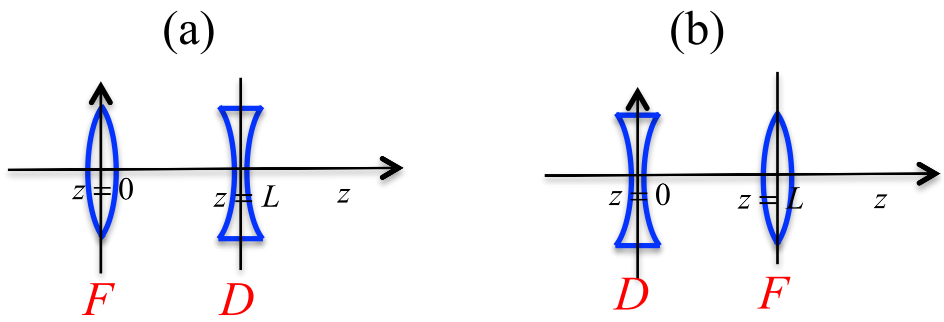


Fig.1. Two combinations of a doublet: *FD* and *DF*.

1. (3 points) Find focal lengths of *FD* and *DF* doublets. For the case of $f_1 = f_2 = f$, show that they are equal and given by following expression:

$$F_{doublet} = \frac{f^2}{L}$$

2. (2 points) The ray (trajectory) parallel to the axis is entering the FD or DF system of lenses. Using you calculation of the trajectories in *FD* and *DF* doublets for $f_1 = f_2 = f$, determine location of to the ray crossing the axis and find their difference between *FD* and *DF* doublets. Since a quadrupole focusing in horizontal plane is defocusing in vertical plane - and visa versa –by solving this your find astigmatism of a doublet built from two quadrupoles, i.e. difference between locations of the focal planes for horizontal and vertical direction of motion.

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