Homework 488/688

Advanced Topics in Accelerator Physics (Hoffstaetter)

Due Date: Monday, 9/13/04 - 14:45 in 132 Rockefeller Hall

Exercise 1 : Assume that the earth has an exact dipole magnetic field which is oriented parallel to the rotation axis. Protons of what energy could you store in a bare vacuum pipe around the equator. What energy of electrons could you store? How much of their energy would these electrons lose during one turn? Use that the magnetic field at the poles is about $2 \cdot 10^{-5}$T.

Exercise 2 : A circular accelerator with dipoles of 100m bending radius stores an electron current of 0.1A at 5GeV. How much power is required to compensate for the emission of synchrotron radiation? How much power would be required to accelerate this electron current to 5GeV in a linear accelerator?

Exercise 3 : Check that the LHC with it's 7TeV protons should be listed for 10^{17}eV on the Livingston Chart. Where should the LEP collider with 100GeV electrons be on this chart? For any collision experiment with center of momentum energy $E_{c.m.}$, the Livingston chart shows how much energy a proton or electron would need to create the same center of momentum energy in a collision with a proton at rest.

Exercise 4 : Show what fields are created when a n pole is shifted by a distance Δ in the transverse direction. For example, show that a shifted sextupole has a quadrupole field.

Exercise 5 : Dipole magnets are used to guiding charged particles in a beam line or circular accelerator. Neutrons cannot be guided by homogeneous magnetic fields since they have no charge. However, due to their magnetic dipole moment the Stern-Gerlach Force could be used to guide them. Which type of multipole magnet would you use for that? What would the multipole strength need to be to produce a bending radius of 10m for a neutron with an energy of 1MeV?

Exercise 6 : Derive the 6 dimensional transport matrix for
A) a quadrupole magnet with length L and quadrupole coefficient k. Make a separate calculation for positive and for negative k.
B) a combined function magnet with length L, curvature κ and quadrupole coefficient k. Use $K = k + \kappa^2$ and distinguish the cases $k > 0$, $k < -\kappa^2$, and $-\kappa^2 < k < 0$.
C) Check that the time of flight could have been computed from the condition $\vec{T} = -\mathbf{J}_4\mathbf{M}_4^{-1}\vec{D}$ due to symplecticity.