# Introduction to Particle Accelerators

# TUTORIAL 1 QUESTIONS

## 1 Synchrotrons

1. Consider a proton synchrotron with a maximum energy of 10 GeV with a magnetic field ramping to 1.5 T in 1 second.
   1. What is the proton momentum (GeV/c) when the field reaches 1.5 T?
   2. What is the value of Bρ at top energy?
   3. If 2/3 of the circumference are filled with bending magnets, what are ρ (bending radius) and R (geometrical radius)?
2. *A synchrotron of 25m radius accelerates protons from a kinetic energy of 50 MeV to*

*1000 MeV. What is the maximum energy of a deuteron beam (Z=1, A=2) that could be accelerated in the machine?*

## 2 The earth magnetic field

1. Let’s build a real cheap storage ring. Just put it to the North Pole and use the magnetic field of the earth whose field lines are perpendicular to the surface at that nice place. Forget about focusing … what will be the size of the ring for a 10 keV electron beam if the earth magnetic field is about 0.5 Gauss? (1 Gauss = 10-4 T).
2. In which direction do you have to circulate the electrons to get stored beam?

## 3 Beam rigidity, particle momentum and the geometry of a storage ring

A storage ring is designed for a proton beam with a momentum of p=920GeV/c.

1. Calculate the corresponding beam rigidity.
2. If the 9m long dipole magnets for this machine can create a magnetic field of 5 T, what will be the bending radius of the design orbit and how many magnets do you have to buy ?
3. Assuming a fill factor for the dipoles in the machine of 60% (a realistic number)

what will be the circumference of the machine ?

1. Your beam optics experts tell you, that they need a normalized focusing strength in the quadrupole lenses of k=0.03364/m2. What is the corresponding gradient and the pole tip field if the aperture radius of the magnets is 30 mm.

## 4 Synchrocyclotron and cyclotrons

1. The CERN synchrocyclotron accelerates protons up to 600 MeV. Compute the maximum orbit radius, considering a constant magnetic field of 1.9 T. Compute the revolution frequency as a function of the radius. Is it possible to change the radial profile of the field to obtain a constant revolution frequency as a function of the radius?