Accelerator Physics Exercises No. 1

- Work to be handed in on 17 October 2018

Question 1.1

A possible new 50 GeV (kinetic energy) proton synchrotron, the PS2 accelerator, has been considered to replace the CERN PS. The new accelerator would sit in a new ring tunnel which has a mean radius of 215 m. and will receive an injected beam at 4 GeV (kinetic energy) from a new linear accelerator - the Superconducting Proton Linac (SPL). The 1.8 T magnetic field of the bending magnets is excited by a sine wave which oscillates between injection and top energy at a frequency of 0.3 Hz. Given that the mass of the proton is 0.9383 GeV:

a) What is the momentum at 4 GeV and at 50 GeV?

b) Given that the magnetic rigidity is defined as $B\rho = 3.3356p\ [Tm]$, where B is the magnetic field, ρ is the bending radius and p is the particle momentum, what is the magnetic rigidity $B\rho$ at both 4 GeV and at 50 GeV?

c) What is the bending radius, ρ?

d) What is the fraction of the ring filled with dipole magnets?

Question 1.2

A betatron has a beam radius of 0.2 m and is powered from 50 Hz mains. Its peak guide field is 0.8 T while the flux linking the orbit is twice that which would result from a uniform field of this value. What will be the peak energy of the electrons it accelerates?

Question 1.3

Using classical mechanics show that the *angular frequency* of revolution of a proton in a cyclotron is equal to $B_z(e/m)$. Now calculate the *revolution frequency* of the protons in a cyclotron with a field of 1.5 T.

Question 1.4

a) Calculate the lifetime of a muon circulating in a storage ring (a) at 50 GeV and (b) at 4 TeV.

b) Calculate the magnetic rigidity $B\rho$, bending radius ρ and circumference of the ring for a 6 T superconducting muon storage ring. Assume $\rho / R = 0.7$.

Question 1.5

a) Synchrotron light of 1 Å is a useful probe for molecular structure. Compare its resolving power with the scale of crystal structure, DNA, organic molecules (e.g. benzene), simple atoms and nuclei.

b) What energy neutrons give a comparable resolution to a synchrotron light of 1 Å?

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