Accelerator Physics Exercises No. 1

- Work to be handed in on 19 October 2022

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 $B_z(e/m)$. Calculate this frequency for a field of 1.5 T (e/m = 9.58 x 10^7 C/kg).

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 $\rho / R = 0.7$, where R is the mean radius of the ring.

Question 1.5

a) Compute the energy loss per turn for a 3 GeV electron beam at Diamond. The magnet bending radius is 7 m.

b) 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.

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

Question 1.6

a) The LHC collides protons (m_{proton} = 0.938 GeV) at 7 TeV per beam. What is the equivalent proton beam energy required to produce the same centre-of-mass energy with a stationary hydrogen target?

b) How fast would you need to drive your new 1.3-ton Mini Cooper to have the same kinetic energy as a bunch of 1.15×10^{11} protons?

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