Tutorial : Accelerators

1. For the original Berkeley Cyclotron (R=12.5 cm, B=1.3 T) compute the maximum proton energy (in MeV) and the corresponding frequency of the varying voltage.

2. Assuming a magnetic field of 1.4 T, compute the maximum energy of protons, deuterons and alphas that can be obtained from a cyclotron of 75 cm radius.

3. A Van de Graaff accelerator uses a spherical terminal with a radius of 2m, which is charged to 2.0×10^6 V. (a) What is the total charge on the terminal ? (b) If the charging belt can carry 0.1 mA, how long will it take to charge the terminal ?

4. The original design of the Berkeley 184-inch synchro-cyclotron gave 350 MeV protons using a magnetic field of about 1.4 T. (a) At what radius should the protons be extracted ? (b) What is the necessary range of cyclotron frequencies ? (c) How long does it take to accelerate a particle ? (d) What is the maximum pulse rate in the beam ?

5. In the drift tube potion of the LAMPF accelerator, protons are accelerated from 0.75 to 100 MeV. The ac voltage has a frequency of 200 MHz. Find the lengths of the first and last drift tubes.
   (Hint : Assume you may use non-relativistic formulae)

6. Discuss the similarities and differences in the phase stability in a linear accelerator and in a synchro-cyclotron.

7. Because accelerated charged particles radiate energy, a beam travelling a circular path must radiate. The energy loss per cycle is

$$\Delta E = \left(\frac{4\pi}{3}\right)\left(\frac{e^2}{4\pi\epsilon_0 R}\right)\left(\frac{E}{mc^2}\right)^4$$

   where E is the total relativistic energy of the particle and R is the radius of its orbit. For each of the accelerator types : cyclotrons, synchro-cyclotrons, synchrotrons and linacs, discuss the relative radiation losses for both electron and proton beams. Consider parameters typical of the larger machines considered in Krane.