Problem Set 1: Introduction to Accelerator Physics

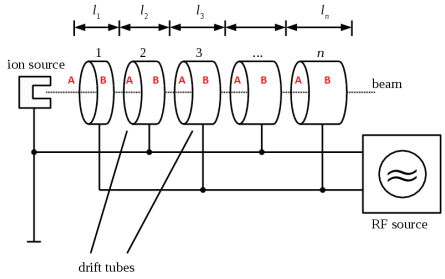
Monday, August 17, 2015

Problem 1

a) How much faster is an electron with $\gamma = 10$ than an electron with $\gamma = 5$?
b) What is the energy (in MeV) of a proton with $\gamma = 10$? What about an electron?

Problem 2

What is the length of the 1^{st} and 5^{th} drift section in Widerøe linear accelerator with $f_{RF} = 7\,\text{MHz}$, energy gain in the gap 1 MeV and starting kinetic energy of 100 keV. Calculate for protons and electrons. Assume the accelerating gaps to be very short compared to the drift tubes.



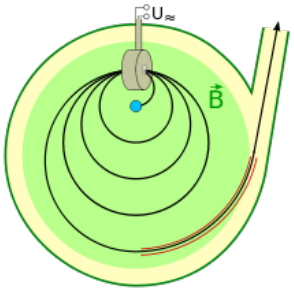
Scheme of a Widerøe linear accelerator.

Problem 3

How large is a microtron with $B = 1.2\,\text{T}$ and $E_{max} = 25\,\text{MeV}$?

Problem 4

ESRF synchrotron is 844.4 m in circumference. It has n = 64 dipole magnets, each $L = 2.45\,\text{m}$ long, and operates at 6 GeV energy. Calculate the bending radius of dipoles r.



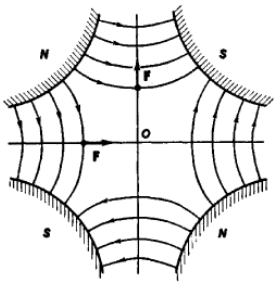
Scheme of a microtron.

Problem 5

A dipole magnet has a 1-turn coil with 400 A.
a) How large should the gap be to produce 0.1 T?
b) How large is the power consumption if you use a copper wire (1 m long) with an area $S = 5\,\text{mm}^2$ and a resistivity $\rho = 1.7 \times 10^{-2}\,\Omega\text{mm}^2\,/\text{m}$?
c) Change to a 20 turn coil using 20 times longer wire. At 0.1 T - how large is the power?

Problem 6

A quadrupole has a strength of 20 T/m and a pole radius of 20 mm. How far from the center do you have to go to find the poles only 1 mm apart?



The magnet pole arrangement for a quadrupole magnet.

Problem 7

The MAX-II ring has $n = 20$ dipoles of $l = 1$ m length. Electrons circulating in the ring have $E_0 = 1.5$ GeV energy, and the circumference of the ring is $C = 90$ m. The RF-cavity has a frequency of $f_{RF} = 100$ MHz. Take the average current in the ring to be $I = 200$ mA.

a) What is the maximum number of bunches can circulate in MAX II?

b) How much charge is there in one bunch and how much in total?

c) How much energy does one electron lose per turn if there are no insertion devices (IDs)?

d) What is the power the cavity needs to supply?(electron charge is $e = -1.6 \times 10^{-19}$ C)