Accelerator Fundamentals Problem Set Monday Week 2

1) A “closed-bump” is an intentionally introduced orbit distortion in a section of beamline. A closed horizontal bump can be made with three horizontal dipole corrector magnets. The first dipole corrector deflects the beam, the second corrector deflects the beam so that it crosses x=0 at the location of the third corrector. The third corrector deflects the beam to remove the residual angle so that x’=0, and the trajectory then remains on the ideal orbit.

Suppose three correctors are located along a beamline. The twiss parameters are β=20m, α=0.1 at the first corrector, β=10m, α=0.05 at the second corrector, and β=25m, α=0.15 at the third corrector. The phase advance between the first and second correctors is 120 degrees, and the phase advance between the second and third correctors is 80 degrees. The first corrector deflects the beam by 1 mrad. What are the required deflection angles of the second and third correctors to make a closed bump.

2) Weidemann 6.2.

3) Suppose that a particle traveling along the design orbit experiences an angular deflection θ at a point s_o.
a) Show that thereafter it’s motion is given by,

$$x(s) = \theta\sqrt{\beta_o\beta(s)}\,\sin(\varphi(s) - \varphi_o)$$

b) To maximize x(s), how should the betatron function and/or phase advance be chosen at s_o and s?
c) For Case #1 in Weidemann Table 6.1, and for a kick with strength θ=0.1 mrad, find the maximum particle excursion if the kicker is located at: 1) the minimum of the beta function, and 2) the maximum of beta function.

4) In class we derived the expression for the closed orbit of the beam resulting from an angular deflection due to a dipole error. Suppose that there are many uncorrelated angular deflections distributed around a ring which average to zero and have an rms value of θ_{rms}. Then the expectation value of the closed orbit distortion at any point s in the accelerator is given by:

$$\langle u_{co}\rangle = \frac{\sqrt{\beta_{ave}\beta(s)}\sqrt{N}\,\theta_{RMS}}{2\sqrt{2}\,\sin(\pi\nu)}$$

a) Consider a ring that is 250 meters in circumference and beam that operates with a tune of 6.20. Estimate the average beta function in the ring using the smooth approximation.

b) If there are 32 dipoles and 54 quads that contribute to the total rms steering error, and the beta function reaches a maximum of 30 meters in the quads, calculate the maximum expectation value of the orbit distortion in the quadrupoles. Take θ_{rms} as 1 μrad.

b) Repeat the calculation for horizontal tunes of 6.1 and 6.01.   What happens?