Accelerator Fundamentals Problem Set Wednesday Week 2

1. Suppose we have a 20 km circumference electron storage ring with beam energy of 40 GeV and a 10 mA beam current.
   a) Determine the bending radius in identical bending magnets (an isomagnetic lattice) if 80% of the circumference can be used for bending magnets
   b) calculate the synchrotron radiation power
   c) calculate the energy loss for a single electron per turn
   d) if the RF cavity system has harmonic number 33200 ($f_{RF}=hf_{rev}$), and the synchronous phase is $\varphi_s=140$ degrees, what is the total accelerating voltage V_0 (where $V(t)=V_0\sin(\omega t)$) needed to replenish the energy lost to synchrotron radiation?
   e) If the average value of the dispersion function is 0.5 meters, for the parameters above, what is the momentum compaction factor?
   f) for the parameters above, what is the synchrotron tune?
   g) for the parameters above, what are the damping times in all three planes?

2. A ring has a circumference of $C=2\pi R=250$ meters. The ring circulates a 1 GeV proton beam with normalized emittance $\varepsilon_N=30$ mm*mrad, and line density $N=4\times10^{11}$ protons/meter.
   a) Calculate the space charge tune shift. (Note $r_o=1.53\times10^{-18}$ meters).
   b) The horizontal tune of the ring is 6.42. Assuming that your machine is limited by the closed orbit instability (integer resonance), resulting from large magnet steering errors, calculate the maximum particle line density allowed.
   c) Starting from the line density calculated in (b), find the total number of particles which can be accumulated in this ring, according to the resonance limit.