Problem Set 6 — due Wednesday, 2018 January 24, 9:00 a.m.

1. **Chasman-Green.** Modern light sources have strong achromatic sections used to control the dispersion function through the bending magnets in order to generate small beam sizes. On the other hand, such strong focusing systems produce high natural chromaticity which must be compensated using sextupole magnets. Suppose a light source is made up of 24 identical sections, and in each section a sextupole magnet is present at locations where the dispersion function has values of $D = 0.5$ m and the amplitude function has value $\beta_x = 25$ m. The natural chromaticity in the horizontal plane is $\xi_x = -96$.

   (a) What value of the sextupole strength $S = B''l/2B\rho$ is required to bring ξ_x back to zero?

   (b) If the vertical amplitude function at this location is $\beta_y = 11$ m, how is the natural chromaticity in the vertical plane affected?

   (c) What would you suggest be done to the accelerator system in order to bring both ξ_x and ξ_y to zero simultaneously?

2. **Synchrotron Radiation Power.** A storage ring synchrotron light source stores a 3 GeV electron beam with 200 mA stored current. The ring has 48 bending magnets with a uniform bending field of 1.2 T.

   (a) Calculate the total synchrotron radiation power (in kW) for one revolution of the machine.

   (b) What is the synchrotron radiation power (in kW) emitted at a single bending magnet?

3. **Energy Loss per Turn.** A $3\tilde{\text{G}}$eV electron beam is stored in an electron storage ring (bending radius 10 m, revolution period 1.87 μs). Because electrons lose a significant amount of energy to synchrotron radiation each turn, RF voltage is required to replenish energy lost each turn.

   (a) What is the energy loss per turn (in MeV) for a single electron due to the bending magnets?

   (b) Calculate the total gap voltage (in MV) required to store electrons with a synchronous phase of 20° from the zero-crossing of the RF.

   (c) Assume the RF trips. If the maximum horizontal dispersion $\eta_x = 0.6$ m and the radius of the vacuum chamber is 5 cm, how many turns will it take for the beam to hit the vacuum chamber? Assume a constant energy loss per turn for a beam at 3 GeV.

4. **Synchrotron Radiation Spectrum.** Beams of lead nuclei ($^{208}\text{Pb}^{82+}$) in the Large Hadron Collider produce synchrotron radiation. Hint: assume $m_u = 0.931$ MeV/c^2.

   (a) What is the critical photon energy (in eV) of a lead nucleus at collision energy (2.563 TeV/U), if the bending radius is 6 km?

   (b) What is the critical photon energy in eV of a lead nucleus at injection energy (177.4 GeV/U), if the bending radius is 6 km?

(c) A short, two period undulator with field 5 T and period 28 cm is used to produce undulator radiation. If lead nuclei are at injection energy (177.4 GeV/U), what is the photon energy in eV of the first undulator harmonic on axis?