PHY 554 Mid-term exam (total 100 pts)

1. **Light source and DBA (30 pts)**
   NSLS-II at BNL is a third generation light source, which adopts DBA lattice (each DBA cell is illustrated in Fig. 1)

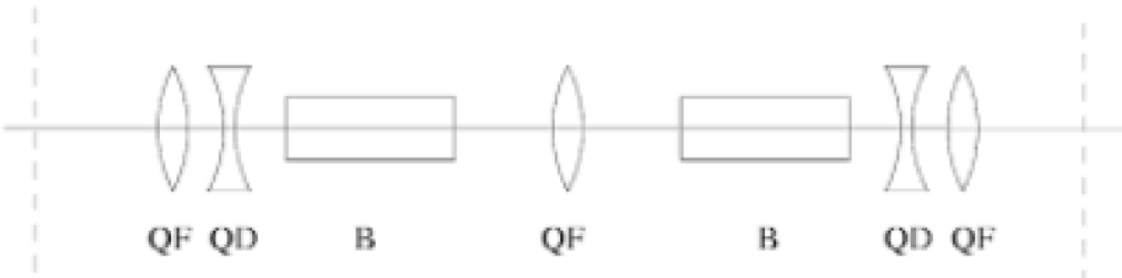

Figure 1: DBA lattice

The parameter of the electron ring is given by the following table.

Table 1: NSLS II parameters

Parameters	Values
Energy [GeV]	3.0
Circumference [m]	780
Number of dipoles	60
Dipole field [T]	0.4
Beam current [A]	0.5
RF frequency [MHz]	499.68
Harmonic number	1320

Using the design parameters in the table, find the answers of the following questions:

a) (10) Find the length of the dipoles assuming they are all equal (Hint: use beam rigidity)

b) (10) In DBA lattice, dispersion D and dispersion slope D′ are zero at both end. Find dispersion function inside the dipole magnet (as the distance s into the dipole).

c) (10) Find the momentum compaction factor $\alpha_c = \frac{1}{C}\oint \frac{D}{\rho} ds$

2. **Synchrotron Radiation (30 pts, each 5 pts)**

i) The LHC accelerates the proton beam to 7 TeV in a superconducting storage ring with a 26.7 km circumference. The magnetic field in the superconducting bending dipole is 8.3 Tesla. Calculate:

a) The radiation energy of the 7 TeV proton per turn
b) The critical energy of the photons
c) The Radiation power for a beam current of 800 mA

ii) The LHC tunnel (Hint: thus same bending radius with scaled B field in dipoles) was used for the LEP (large electron project). LEP accelerates the electron beam to 100 GeV, the highest electron energy achieved in a collider. Calculate:

d) The radiation energy of the 100 GeV electron per turn
e) The critical energy of the photons
f) The Radiation power for a beam current of 800 mA

3. **Dispersion suppressor with FODO cell (20 pts)**
For a FODO cell with dipole and quads (QF/2, B, QD, B, QF/2), we find the optics at the middle plane of the focusing quad are β_F and D_F, from the periodic boundary condition. The phase advance of the cell is ϕ.
a) (5) Find the 3 by 3 matrix M for the cell using known parameters (β_F, D_F, and ϕ). (Hint: what is α_F, γ_F and D_F'? Write 2 by 2 matrix using Courant-Snyder parameterization and then construct 3 by 3 matrix)
b) (5) To match the cell's dispersion function to zero, we need to attach a dispersion suppressor to its end. Show that using the same FODO cells with zero bending angle will not do the job.
c) (10) To design a proper suppressor, we can use another two FODO cells with reduced bending angles. The cell 1 has bending angle θ_1 and cell 2 has bending angle θ_2. Find θ_1/θ and θ_2/θ using known parameters (θ is the main FODO cell's dipole's angle).

4. **Heat load in a cavity (20 pts)**
In RF cavity operating at 500 MHz, amplitude of the magnetic field at the part surface is 500 Gs or 500 Oe. Find power losses per square meter of the surface for:
(a) (10) Cu cavity*
(b) (10) SRF cavity with surface resistance, $R_s = 5\ 10^{-9}$ Ohm.

How much water you can heat from 20 C° to 40 C° in one hour (3,600 second) by cooling such Cu cavity?

Hint: you may use the conductivity of Cu or scale R_s from results shown in Lecture 12. Thermal capacitance of water is 4,179 J/kg/ C^o.