JUAS 2017, Synchrotron Radiation exam (2 pages)

The following constant will be used in the exercises

elementary electric charge	$e = 1.6\cdot10^{-19}$ C
velocity of light	$c = 2.998\cdot10^{8}$ m/s
reduced Planck constant	$\hbar = h/2\pi = 1.05\cdot10^{-34}$ Kg m^2/ s
vacuum dielectric constant	$\varepsilon_0 = 8.854\cdot10^{-12}$ F/m
electron rest energy	0.511 MeV
proton rest energy	938 MeV
classical electron radius	$r_e = 1/(4\pi\varepsilon_0)\, e^2/(mc^2) = 2.81\cdot10^{-15}$ m

$$C_q = \frac{55}{32\sqrt{3}}\frac{\hbar}{mc} = 3.84\cdot10^{-13}\,\mathrm{m}$$

Solve at least 3 of the following 4 exercises. (All exercises have the same value).

Ex. 1:
Consider an electron storage ring operating at 3 GeV, with a lattice made of 24 DBA cells.

a) give an estimate for the minimum emittance achievable in such ring (take J_x = 1).
b) If the magnetic field of the dipole is 1.4T calculate the critical energy of the bending magnets

Assume we want to upgrade this lattice to a 48 DBA cells.

c) give an estimate for the minimum emittance achievable in such ring.
d) Assuming that the length of each dipole has not changed in the upgrade, calculate the new critical energy for the dipole radiation.
e) Describe what is the change in the characteristics of the bending magnet radiation (i.e. power, spectrum and angular distribution).

Ex. 2:
Consider an electron storage ring operating at 6 GeV. The injection process requires that the oscillations of the injected beam at 6 GeV are damped within 10 ms, otherwise the injected beam hits the back of the septum magnet and no injection is possible.

a) What is the energy loss per turn necessary to guarantee the damping time required for injection (take J_x = 1 and a revolution time $T_0 = 2\mu$s).
b) If the energy of the ring reduced to 3 GeV, what is the energy loss per turn necessary to guarantee the injection with the existing injection system parameters?
c) If we want to use damping wiggler to guarantee the injection at 3GeV and L_W = 50 m are available, what is the magnetic field B_W required from the damping?
d) What are the main effects of the introduction of damping wigglers on the equilibrium beam parameters?

Ex. 3:

In a 3 GeV electron synchrotron, a beamline is made by an undulator of length L = 2 m, operating at a wavelength λ = 1nm. The emittance of the ring is 1 nm in both planes and the optics function at the middle of the straight section are $\beta_x = \beta_y$ = 5m and $\alpha_x = \alpha_y = 0$ and the dispersion function is zero.

The beamline has a round slit aperture at 20 m downstream with radius r = 1 mm.

a) is the undulator fan at λ = 1nm passing through the slit? (assume a Gaussian beam for the undulator radiation)
b) What happens if the optics function in the middle of the straight section are reduced to $\beta_x = \beta_y$ = 1m? Give an estimate of the change in flux through the slit.
c) Describe the criteria to achieve the optimal matching of the electron phase space and the photon phase space at the centre of the undulator.

Ex. 4:

Describe the strategies for the design of the linear optics functions β, α and dispersion D in as low emittance lattice. What are the most common solutions? Sketch the optics functions required to achieve the theoretical minimum emittance in a TME and DBA lattice.