Problems for the exam of the JUAS 2012 session on "Synchrotron Radiation"

Physical constants:

dielectricity	$\varepsilon_0 = 8.85419 \cdot 10^{-12}$ As/Vm
velocity of light	$c = 2.997925 \cdot 10^{8}$ m/s
elementary charge	$e = 1.60203 \cdot 10^{-19}$ C
mass of an electron	$m_e = 9.1081 \cdot 10^{-31}$ kg
	$= 510.974$ keV
mass of an proton	$m_p = 1.67236 \cdot 10^{-27}$ kg
	$= 938.211$ MeV
Planck's constant	$h = 6.6252 \cdot 10^{-34}$ J s
	$\hbar = \dfrac{h}{2\pi} = 1.05443 \cdot 10^{-34}$ J s

Problem 1 (Short question, no calculation required)

In order to design a modern storage ring for synchrotron radiation a very small beam emittance is required. Describe shortly the most important design criteria to fulfill this requirements. At least 3 criteria should be specified.

Problem 2

a) An electron flying through the space with the energy E passes the earth. It is bend by the magnetic field of the earth of $B_{earth} = 3 \cdot 10^{-5}$ T and emits at this time a photon spectrum with a critical wavelength of $\lambda_c = 450$ nm (i.e. blue light). What is the energy E of the electron.

b) The electron travels along a trajectory of a total length of $L = 1000$ km. How much energy has the electron lost along this passage due to synchrotron radiation? (The influence of the air has to be neglected, assume pure vacuum)

Problem 3

An electron storage ring with the design energy of $E = 3.5$ GeV contains n identical bending magnets with identical beam optics. We assume that all magnets fulfil the Chasman-Green condition. The horizontal emittance is supposed to be $\varepsilon_x = 3 \cdot 10^{-9}$ m rad.

a) How many bending magnets are at least required in the lattice?

b) How long are the bending magnets (i.e. the length of the trajectory in the magnet), if the field strength is $B = 1.5$ T?

Problem 4

A linac provides an electron beam with very small transverse dimensions. The beam energy is $E_b = 100$ MeV. Behind the linac a permanent magnet undulator with a periode length of λ_u =15 mm is installed. The pole tip field is $B = 0.9$ T. This undulator produces a coherent radiation with a wavelength of $\lambda = 290$ nm.

a) Calculate the required gap height of the undulator.

b) How long is the magnet in order to get a line width of $\Delta\lambda/\lambda = 5 \cdot 10^{-3}$?

GOOD LUCK !