JUAS 2013 exam (K. Wille)

The following constant will be used in the exercises

velocity of light	$c = 2.998 \cdot 10^{8}$ m/s
reduced Planck constant	$\eta = h/2\pi = 1.05 \cdot 10^{-34}$ Kg m^2/ s
vacuum dielectric constant	$\varepsilon_0 = 8.854 \cdot 10^{-12}$ F/m
electron rest energy	0.511 MeV
proton rest energy	938 MeV
classical electron radius	$r_e = 1/(4\pi\varepsilon_0)\, e^2/(mc^2) = 2.81 \cdot 10^{-15}$ m

Ex. 1:

a) give a short explanation why charged electrons emit almost no radiation during longitudinal acceleration, for instance in a LINAC;

b) what is the reason to use electron beams as a source of synchrotron radiation instead of other particles as muons and protons?

Ex. 2:

A proton with energy $E_p = 10$ TeV moves through the magnetic field of a neutron star with strength $B = 10^8$ T. We assume that at the position of the proton the field is homogenous.

a) Calculate the diameter of the proton trajectory and the revolution frequency
b) How large is the power emitted by synchrotron radiation?
c) How much energy does the proton lose per revolution?

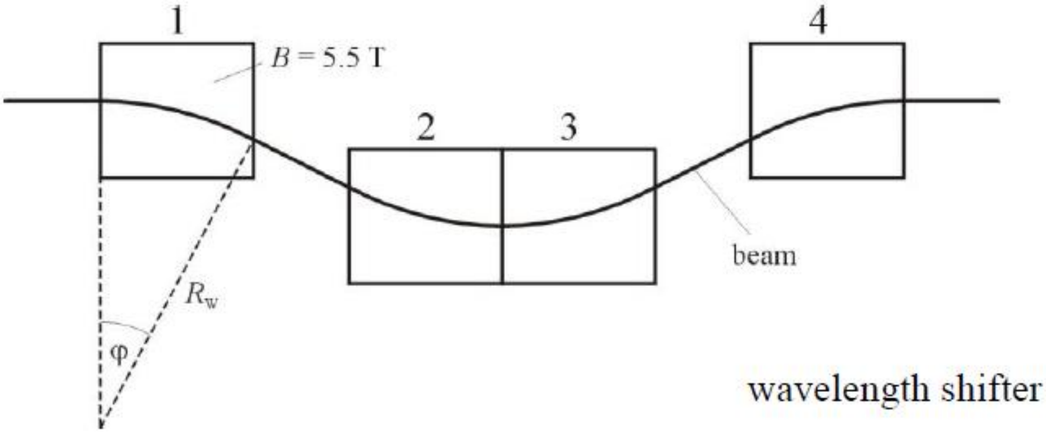
Ex. 3:

From the bending magnet of an electron storage ring synchrotron radiation should be emitted with a critical energy of $E_c = 1.2$ keV. The bending radius of the magnets is R = 5.5 m.

a) What is the required energy of the electron beam?
b) A maximum beam current of Imax = 250 mA has to be stored in the machine. How much RF power is at least required? We assume that 50% of the power is transferred to the beam and 50% lost in the cavities.

In order to get higher critical photon energy in one insertion a “wavelength shifter” is installed. It consists of 4 identical short bending magnets. The homogeneous field in the dipoles amounts to B = 5.5 T. Each magnet bends the beam by an angle $\varphi = 10$ degrees (see Fig. below)

c) Calculate the critical energy of the radiation emitted by the wavelength shifter. By what amount the power of the RF system has to be increased to compensate the additional energy loss produced by the wavelength shifter



Ex. 4: low emittance lattices

An undulator has total length L = 5.3 m and the period λ_u = 50 mm. The pole tip field is B_0 = 1.2 T. The gap height can be varied between the limits of g = 20 mm and g = 60 mm.

a) The undulator is installed in a storage ring operating with an electron beam energy E_b = 2.9 GeV. What wavelength range is covered by the emitted coherent radiation of the first harmonics? What is the relative width of the radiation spectrum? The radiation is measured at the radiation axis ($\theta = 0$).

b) The same undulator is adjusted at a fixed gap of g = 40 mm. What beam energy E_b is needed to get coherent infrared radiation with a wavelength of λ = 5 μm?