Problems for the exam of the JUAS 2013 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 $\hbar = \frac{h}{2\pi} = 1.05443 \cdot 10^{-34}$ J s

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Problem 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 for synchrotron radiation instead of other particles as muons or protons?

Problem 2

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

a) Calculate the diameter of the proton trajectory and the revolution frequency.

b) How large is the power of the emitted synchrotron radiation?

c) How much energy loses the proton per revolution?

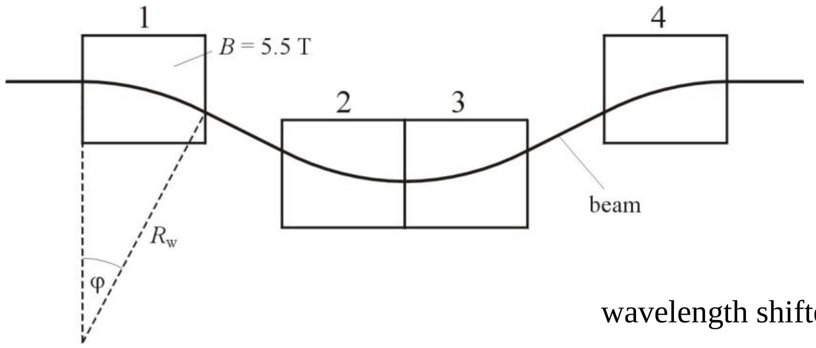
Problem 3

From the bending magnets 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 I_{max} = 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.

c) In order to get a 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 of φ = 10°



wavelength shifter

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.

Problem 4

An undulator has the total length of L = 5.3 m and the period length of 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 of E_b = 2.9 GeV. What wavelength range is covered by the emitted coherent radiation of the first harmonic? What is the relative line width of the radiation spectrum? The radiation is measured at the radiation axis ($\Theta = 0$).

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

GOOD LUCK !