Nuclear Instrumentation : Particle Accelerators

Exercises 2022 - 2023

You should try to solve the following three exercises and submit your individual reports in a PDF file via email to willy.mondelaers@ugent.be **not later than January 9, 2023**.

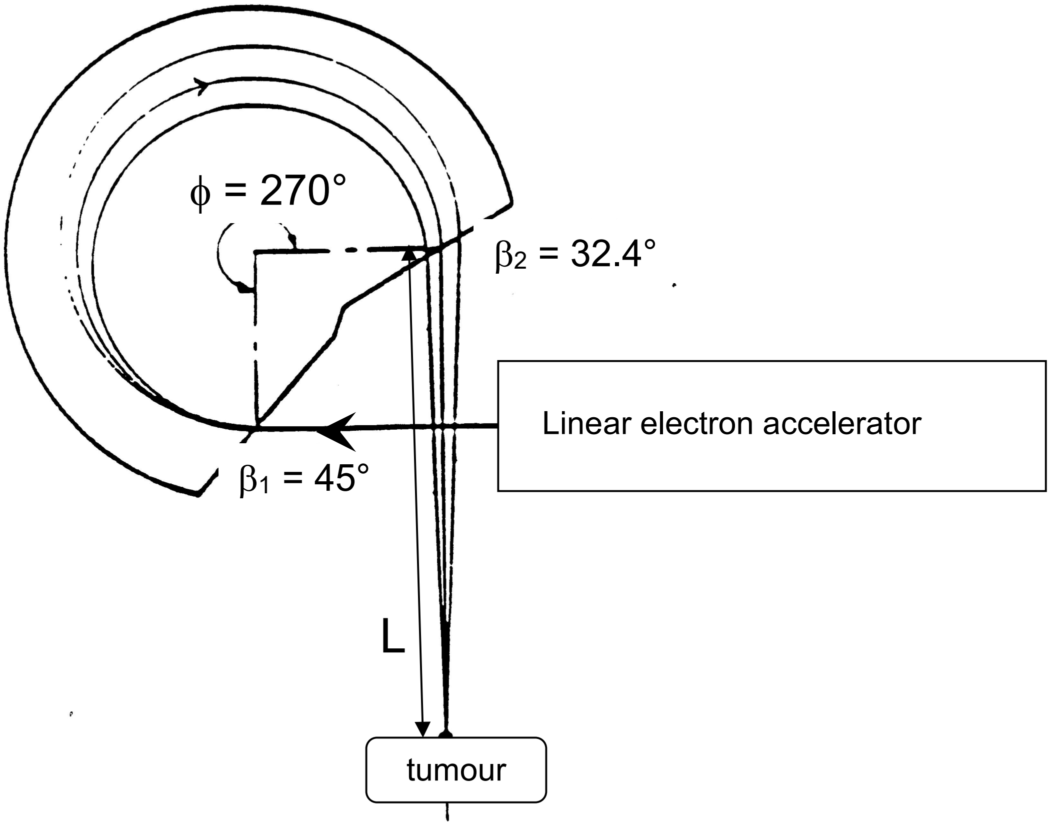
We will discuss shortly your report at the exam. Two out of the eight points for the 'accelerator part' of the course can be scored with these exercises.

Kind regards,

W. MONDELAERS

EXERCISE 1

A medical irradiation facility produces an electron beam with a kinetic energy of 20 MeV. A homogeneous dipole bending magnet is placed after the accelerator. It bends a charged particle beam over 270°. The pole shoe edge at the entrance is rotated over 45°, while the edge at the exit is rotated over 32.4°. It directs the electron beam towards the tumour of the patient at a distance L from the magnet exit.

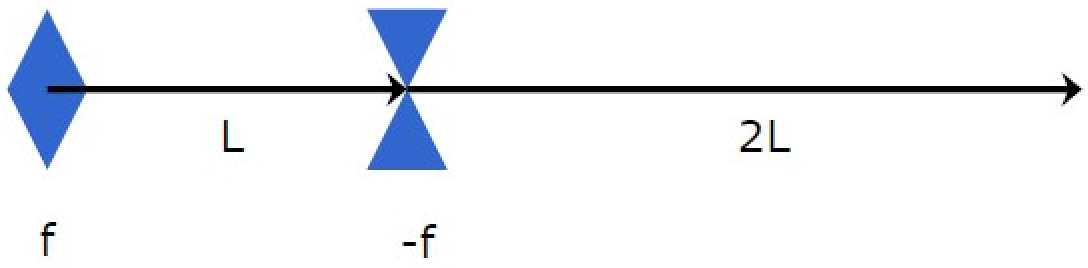


If we perform an irradiation of a skin tumour with electrons it is extremely important to focus all electrons in the same point on the tumour. If we suppose that a parallel beam is entering the magnet, calculate the distance L at which the magnet is 'triple focusing' (that is, the magnet is parallel-to-point focusing in both, horizontal and vertical planes and it is also non dispersive).

Suppose that the magnet has a gap between the pole shoes of 3 cm and that the magnet coils are excited with a current of 40 A. What is the number of coil windings needed to allow positioning of the tumour at a distance of 50 cm below the magnet? ($\mu_0 = 4\pi.10^{-7}$ Tm/A).

EXERCISE 2

Consider the following FODO cell. Particles are moving from left to right. In the horizontal plane the first lens is focusing, the second defocusing.

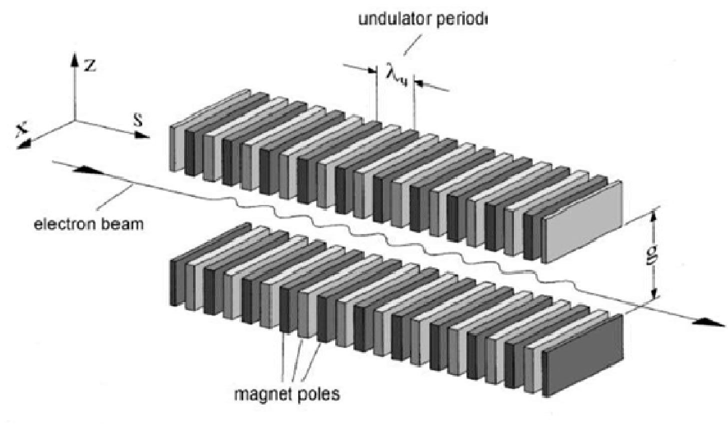


1. Write the horizontal transfer matrix for this cell (in thin-lens approximation).
2. If a ring is made of these FODO cells, express the condition for stable orbits in the horizontal plane as an inequality between L and f.
3. Under this condition, will the motion in the vertical plane be stable as well?

EXERCISE 3

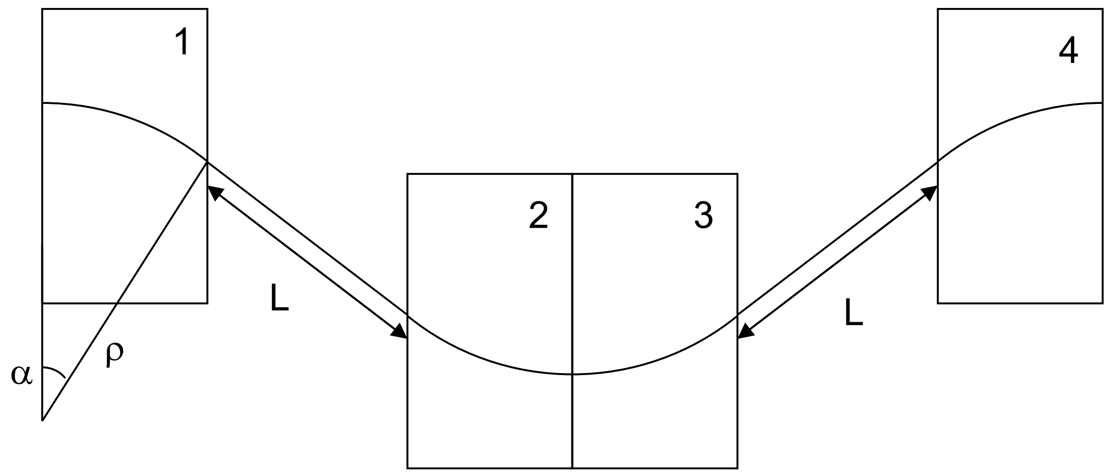
Synchrotron radiation can be generated with undulators. Undulators are periodic dipole magnets, in which the electrons perform an oscillating motion.

Undulators are built using homogeneous rectangular dipole magnets. Rectangular magnets are magnets with parallel pole shoe edges (see for example magnet 1 in the figure below).



What is the transfer matrix for the motion in the median plane in one rectangular magnet, bending over an angle α and having a bending radius ρ? (Suppose that the optical axis at the entrance of the magnet is perpendicular to the pole shoe edge).

We have now a system of magnets that is composed of 4 identical rectangular magnets. All 4 magnets have the same homogeneous dipole field, but the fields in the magnets 2 and 3 are reversed compared to those in the magnets 1 and 4. The drift pieces between magnet 1 and 2, and between 3 and 4 have a length L, while the distance between magnet 2 and 3 is negligible.



Show that this system of four magnets is always achromatic, irrespective of the distance L.

Calculate the transfer matrix of the system if the distance L can be put equal to zero. Calculate also for this case the undulator parameter $K = \lambda_u/2\pi\rho$.

What is the wavelength of a FEL with an undulator having a bending radius ρ = 16 cm and a bending angle $\alpha = 45^o$? The kinetic energy of the electrons in the undulator is 400 MeV.