

You can answer in English or in Finnish. Voit vastata englanniksi tai suomeksi.

1. The average magnetic field at outer radius (extraction) of a cyclotron is 1.7 T and extraction radius is 105 cm. What is the energy for ${}^4\text{He}^{2+}$ and ${}^{132}\text{Xe}^{17+}$?
2. A focusing doublet consists of two short lenses with a drift space between them. The focal length of the first lens is f_1 (>0) and the focal length of the second lens is f_2 (<0). The distance between the lenses is d . Calculate the transverse transfer matrix for the system.
Give a condition to the focal lengths so that the doublet is effectively focusing.
3. Explain the operation principle of
 - Classical cyclotron
 - Synchrocyclotron
 - Isochronous cyclotron
4. The geometrical emittance of a 20 keV proton beam is 100π mm mrad. The protons are accelerated further to 50 keV. What is the geometrical emittance then?
5. Extraction from a cyclotron.
6. The cyclotron RF-system (acceleration) operates at a frequency range of 10 – 21 MHz, and it consists of two 78 degree Dee-electrodes (four accelerating gaps). The extraction radius is 94 cm. At which frequencies you can accelerate
 - a) 30 MeV protons
 - b) 60 MeV ${}^4\text{He}$
 - c) 240 MeV ${}^{40}\text{Ar}$

Atomic mass unit u	1.66054×10^{-27} kg
Proton mass	1.007 u
Electron mass	5.4858×10^{-4} u
Unit charge	1.6022×10^{-19} C
Speed of light	2.99792458×10^8 m/s