(16.7) Calculate the maximum energy (a) for protons, deuterons, and helium ions in a cyclotron, whose maximum orbit diameter is 1.25 m and whose frequency is 12 MHz. (b) What magnetic field strength would be required in each case?

Begin with the usual units and definitions:

$u_n := 1.660540 \cdot 10^{-27} \cdot kg$ $\quad c_{light} := 299792458 \cdot m \cdot sec^{-1}$ $\quad MeV := 1.6021773 \cdot 10^{-19+6} \cdot joule$

$f := 12 \cdot MHz$ $\quad d_{max} := 1.25 \cdot m$ $\quad r_{max} := \frac{d_{max}}{2}$

$q_e := 1.6021773 \cdot 10^{-19} \cdot coul$ $\quad v_{proj} := f \cdot 2 \cdot \pi \cdot r_{max}$ $\quad v_{proj} = 4.712 \cdot 10^{7} \ \cdot m \cdot sec^{-1}$

$\beta := \frac{v_{proj}}{c_{light}}$ $\quad \beta = 0.157$ $\quad f_{rel} := \frac{1}{\sqrt{1 - \beta^2}}$

$i := 1..3$ Do all calculations for the three particles in array mode ($i$=1, p+, $i$=2, d+, $i$=3, α):

$M_i :=$

| |
|---|
| 1.00727947 |
| 2.014102 − 0.000549 |
| 4.002603 − 2·0.000549 |

p+-mass,
d+-mass and
α-mass in amu

$z_i :=$

| |
|---|
| 1 |
| 1 |
| 2 |

$m_i := M_i \cdot u_n \cdot f_{rel}$

$E_i := M_i \cdot u_n \cdot \left(f_{rel} - 1\right) \cdot c_{light}^2$ $\quad B_i := \frac{\sqrt{E_i \cdot 2 \cdot m_i}}{z_i \cdot q_e \cdot r_{max}}$

$E_i$

| |
|---|
| $1.892 \cdot 10^{-12} \cdot kg \cdot m^2 \cdot sec^{-2}$ |
| $3.783 \cdot 10^{-12} \cdot kg \cdot m^2 \cdot sec^{-2}$ |
| $7.517 \cdot 10^{-12} \cdot kg \cdot m^2 \cdot sec^{-2}$ |

$B_i$

| |
|---|
| $0.8 \cdot kg \cdot sec^{-1} \cdot coul^{-1}$ |
| $1.598 \cdot kg \cdot sec^{-1} \cdot coul^{-1}$ |
| $1.588 \cdot kg \cdot sec^{-1} \cdot coul^{-1}$ |

OBS !

$1 \cdot kg \cdot sec^{-1} \cdot coul^{-1} = 1 \cdot tesla$

OBS !

$1 \cdot MeV = 1.602 \cdot 10^{-13} \ \cdot kg \cdot m^2 \cdot sec^{-2}$

$Ee_i := \frac{E_i}{MeV}$

$Ee_i$

| | |
|---|---|
| 11.811 | MeV |
| 23.61 | MeV |
| 46.92 | MeV |