Vietnam National University Ho Chi Minh City
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Course Name: Principles and Applications of Accelerator
Course Code/Class Code: ....
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Question 1: The fundamental differences between Cyclotron and Synchrotron

Cyclotron:

- Compact size, space-saving
- Uses a uniform magnetic field
- RF frequency (frf) is constant
- Limited by relativistic effects (cannot accelerate particles with velocities approaching the speed of light)
- The particle trajectory is a circular orbit
- Magnets are placed above and below the two electrodes

Synchrotron:

- Larger size, requires more space
- Magnetic field and RF source frequency are constantly adjusted
- Not limited by relativistic effects (variable frf allows acceleration of particles with high velocities and energies)
- Particles move on a fixed circular trajectory

- Magnets are arranged along the circular circumference

Question 3:

n = 42 drift tubes

f = 100 MHz

w = 500 keV = 0.5 MeV

L_{42} = 32 cm = 0.32 m

$E_{0\ (proton)}$ = 938 MeV

We have:

$$L = \frac{1}{2}vt = \frac{1}{2}v\frac{1}{f}v = c\beta = c\sqrt{1 - \frac{1}{\gamma^2}}$$

$$\Rightarrow L = \frac{1}{2f}c\sqrt{1 - \frac{1}{\gamma^2}}$$

Where:

$$\gamma = \frac{E}{E_0}$$

$$\Rightarrow L_n = \frac{c}{2f}\sqrt{1 - \left(\frac{E_0}{E_n}\right)^2}$$

$$\Rightarrow L_{42} = \frac{c}{2f}\sqrt{1 - \left(\frac{E_0}{E_{42}}\right)^2}$$

$$\Rightarrow 0.32 = \frac{3x10^8}{2x100x10^6}\sqrt{1 - \left(\frac{938}{938+K_0+(42-1)x0.5}\right)^2}$$

$$K_0 \approx 1.6\ MeV$$

Thus, the initial energy of the proton injected into the accelerator is approximately 1.6 MeV.

a) We have:

$$K_n = 50\ MeV = K_0 + (n - 1)w$$

$$\Rightarrow n = \frac{K_n - K_0}{w} + 1 = \frac{50-1.6}{0.5} + 1 \approx 98\ (drift\ tubes)$$

$$\Rightarrow \Delta n = 98 - 42 = 56\ (drift\ tubes)$$

Thus, an additional 56 drift tubes are required to accelerate the proton to an energy of 50 MeV.

Question 4:

We have:

1T = 10^4 G = 10 kG

$$\frac{mv^2}{R} = qvB$$

$$mv = qRB$$

$$mv = \frac{1.6x10^{-19}}{1.6x10^{-10}} x0.1cR(m)B(T)$$

$$\Rightarrow mv = 3x10^{-2}RB = 0.03RB\ (J)$$

Question 5:

Synchrotron: R = 10 m

Proton partical: B = 1.2 T

$E_{0\ (proton)}$ = 938 MeV

a) The particle moves in a magnetic field along a circular trajectory.

We have:

$$\frac{mv^2}{R} = qvB$$

$$mv = qRB$$

$$p = qRB$$

$$\Leftrightarrow pc = qRBc = 0.3RB \qquad (GeV) \quad (1)$$

Where:

$$E^2 = (pc)^2 + (m_0c^2)^2$$

$$\Rightarrow pc = \sqrt{E^2 - (m_0c^2)^2}$$

$$pc = \sqrt{K(K + 2m_0c^2)} \quad (2)$$

From (1) and (2):

$$\Rightarrow 0.3RB = \sqrt{K\left(K + 2m_0c^2\right)}$$

$$0.3x10x1.2x10^3 = \sqrt{K(K + 2x938)}$$

$$\Rightarrow k \approx 2782.19\ MeV \approx 2.78\ GeV$$

$\Longrightarrow$The kinetic energy of the proton is approximately $2.78\ GeV$

b) We have:

$$\gamma = \frac{E}{E_0} = \frac{2.78+0.938}{0.938} \approx 3.96 > 1$$

$\Longrightarrow$ The particle moves relativistically.

$$\Longrightarrow f_{proton} = \frac{zeB}{2\pi\gamma m_0} = \frac{1x1.6x10^{-19}x1.2}{2\pi x3.96x1.67x10^{-27}}$$

$$f_{proton} \approx 4.62\ MHz$$

Question 2:

From the de Broglie wavelength:

$$\lambda = \frac{h}{p}$$

Where p is the momentum of the particle.

We observe that: $\lambda \sim \frac{1}{p}$