Physics 905

Fundamentals of Accelerator Physics.

Problem Set #1

March 3, 2016 due March 17, 2016

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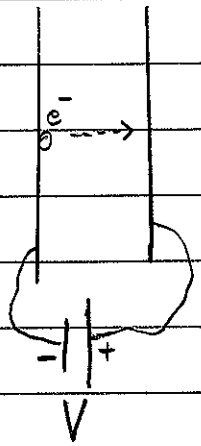
Problem #1 20pts

Particle Velocities.

5pts a) An electron is accelerated between the plates of a parallel plate capacitor biased to potential V starting from rest at the minus electrode.



Give formulas for the final speed v of the electron in the nonrelativistic approximation and relativistically.

5pts b) Plug numbers in a) for $V = 10V$ and $V = 10kV$ for both the nonrelativistic and relativistic formulas. Express answers in m/sec and $\beta = v/c$ units.

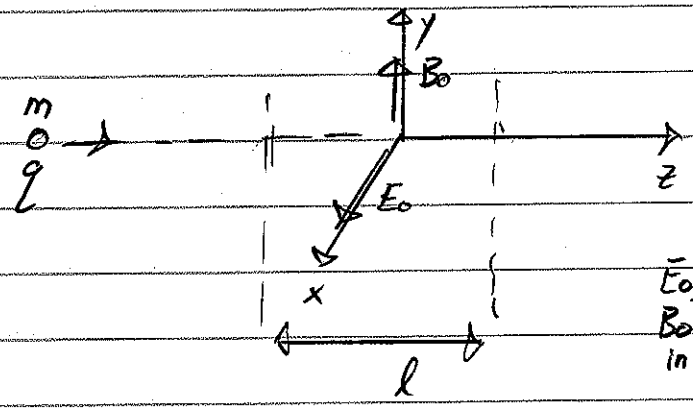
5pts c) Protons in medical accelerators have kinetic energy $\sim 100MeV$. Estimate γ, β, and the speed in m/sec of the protons.

5pts d) In heavy-ion accelerators ion kinetic energies are typically measured in MeV/nucleon. Show how this approximately fixes the particle axial β. Explain why this is desireable in resonant RF accelerators.

Problem #2 30 pts.

Charge to Mass Selector

Positively charged ions with charge q and mass m are emitted from a source and accelerated through a potential difference V_0. The particles enter a "velocity selector" made up of crossed electric and magnetic fields $\vec{E}_0$ and $\vec{B}_0$. Model these fields as uniform over an axial length ℓ.



5 pts a) Find a formula for the value of axial β that the particle will move through the selector without deflection.

3 pts b) What value of β will pass through the selector undeflected for $E_0 = 75$ kV/m and $B_0 = 0.05$ Tesla ?

5 pts c) Assume nonrelativistic motion, show if the magnetic field is turned off ($B_0 = 0$) that particles are deflected through an angle θ, emerging from the deflector with θ satisfying

$$\tan\theta = \frac{1}{2}\frac{E_0 \ell}{V}$$

2pts d) If $\ell = 0.15$ meters, $V_0 = 60\,kV$, $E_0 = 75\,kV/m$ evaluate θ in part c).

Assume E_0 and B_0 are in balance for no deflection.

5pts e) Then the Electric field E_0 is zeroed and the magnetic field is left on at its original value of B_0. Show that particles will be bent on a circular arc of radius

$$R = \frac{2V_0}{E_0}. \qquad E_0 = \text{original field value.}$$

2pts f) Find the value of R for $V_0 = 60\,kV$ and $E_0 = 75\,kV/m$.

3pts g) Show for undeflected particles, that the charge-to-mass ratio is

$$\frac{q}{m} = \frac{E_0^2}{2V_0B_0^2}$$

If ions have charge state $Q = q/e$ and atomic mass $A = m/m_U$ where $m_U = 931\ MeV/c^2$ is the rest mass of a nucleon, this value of q/m corresponds to

$$\frac{Q}{A} = \frac{m_U c^2}{2eV_0}\left(\frac{E_0}{cB_0}\right)^2 = \frac{m_U c^2}{2eV_0}\beta^2$$

5pts h) Use results and parameters above to find the value of Q/A for undeflected ions. If we believe those ions to be Nitrogen, what charge state is most likely?