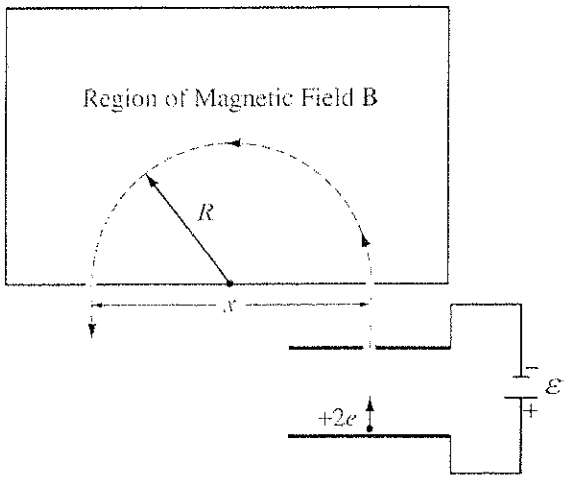
Mass Spectrometer FR Problems



Top View

2. (10 points)

Your research director has assigned you to set up the laboratory's mass spectrometer so that it will separate strontium ions having a net charge of $+2e$ from a beam of mixed ions. The spectrometer above accelerates a beam of ions from rest through a potential difference $\mathcal{E}$, after which the beam enters a region containing a uniform magnetic field **B** of constant magnitude and perpendicular to the plane of the path of the ions. The ions leave the spectrometer at a distance x from the entrance point. You can manually change $\mathcal{E}$.

Numerical values for this experiment:

Strontium atomic number:	38
Strontium ion mass:	1.45×10^{-25} kg
Magnitude of B field:	0.090 T
Desired exit distance x:	1.75 m

(a) In what direction must **B** point to produce the trajectory of the ions shown?

(b) The ions travel at constant speed around the semicircular path. Explain why the speed remains constant.

(c) Calculate the speed of the ions with charge $+2e$ that exit at distance x.

(d) Calculate the accelerating voltage $\mathcal{E}$ needed for the ions with charge $+2e$ to attain the speed you calculated in part (c).

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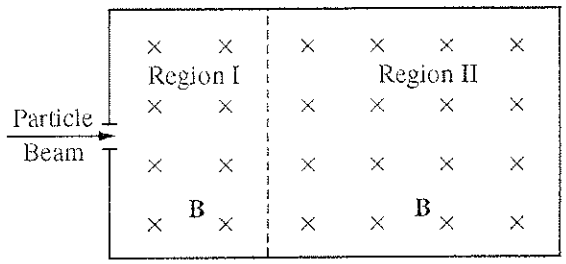


2. (10 points)

A beam of particles of charge $q = +3.2 \times 10^{-19}$ C and mass $m = 6.68 \times 10^{-26}$ kg enters region I with a range of velocities all in the direction shown in the diagram above. There is a magnetic field in region I directed into the page with magnitude $B = 0.12$ T. Charged metal plates are placed in appropriate locations to create a uniform electric field of magnitude $E = 4800$ N/C in region I. As a result, some of the charged particles pass straight through region I undeflected. Gravitational effects are negligible.

(a)

i. On the diagram above, sketch electric field lines in region I.

ii. Calculate the speed of the particles that pass straight through region I.

The particles that pass straight through enter region II in which there is no electric field and the magnetic field has the same magnitude and direction as in region I. The path of the particles in region II is a circular arc of radius R.

(b) Calculate the radius R.

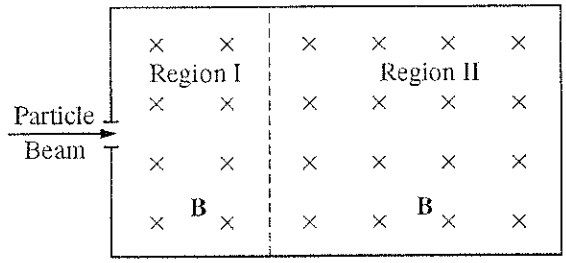
(c) Within the beam there are particles moving slower than the speed you calculated in (a)ii. In what direction is the net initial force on these particles as they enter region I?

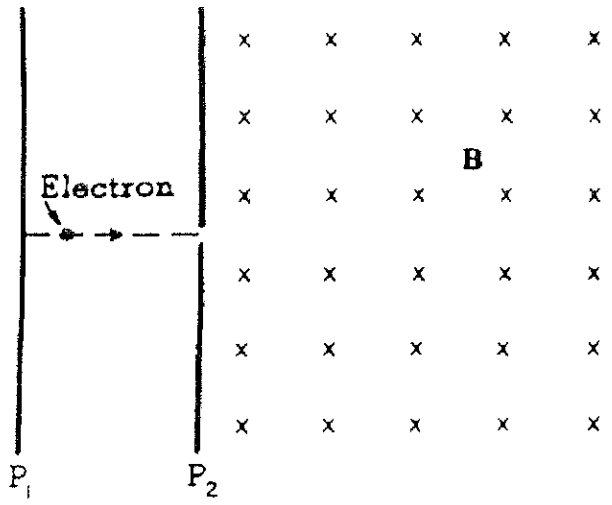
_____ To the left _____ Toward the top of the page _____ Out of the plane of the page

_____ To the right _____ Toward the bottom of the page _____ Into the plane of the page

Justify your answer.

(d) A particle of the same mass and the same speed as in (a)ii but with charge $q = -3.2 \times 10^{-19}$ C enters region I. On the following diagram, sketch the complete resulting path of the particle.





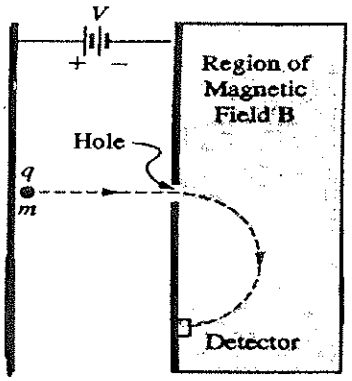
3. An electron is accelerated from rest through a potential difference of magnitude V between infinite parallel plates P_1 and P_2. The electron then passes into a region of uniform magnetic field strength B which exists everywhere to the right of place P_2. The magnetic field is directed into the page.

   (a) On the diagram above, clearly indicate the direction of the electric field between the plates.

   (b) In terms of V and the electron's mass and charge, determine the electron's speed at plate P_2.

   (c) Describe in detail the motion of the electron through the magnetic field and explain why the electron moves this way.

   (d) If the magnetic field remains unchanged, what could be done to cause the electron to follow a straight-line path to the right of plate P_2?



3. A particle of mass m and charge q is accelerated from rest in the plane of the page through a potential difference V between two parallel plates as shown above. The particle is injected through a hole in the right-hand plate into a region of space containing a uniform magnetic field of magnitude B oriented perpendicular to the plane of the page. The particle curves in a semicircular path and strikes a detector. Neglect relativistic effects throughout this problem.

(a) i. State whether the sign of the charge on the particle is positive or negative.

ii. State whether the direction of the magnetic field is into the page or out of the page.

(b) Determine each of the following in terms of m, q, V, and B.

i. The speed of the charged particle as it enters the region of the magnetic field B

ii. The force exerted on the charged particle by the magnetic field B

iii. The distance from the point of injection to the detector

iv. The work done by the magnetic field on the charged particle during the semicircular trip