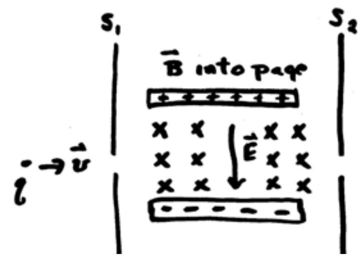
Magnetic Forces
Challenge Problems

Problem 1:

A particle with charge q and velocity $\vec{\mathbf{v}}$ enters through the hole in screen 1 and passes through a region with non-zero electric and magnetic fields (see sketch). If $q < 0$ and the magnitude of the electric field E is greater than the product of the magnitude of the initial velocity v and the magnitude of the magnetic field B, that is $E > vB$, then the force on the particle



a) is zero and the particle will move in a straight line and pass through the hole on screen 2.

b) is constant and the particle will follow a parabolic trajectory hitting the screen 2 above the hole.

c) is constant and the particle will follow a parabolic trajectory hitting screen 2 below the hole.

d) is constant in magnitude but changes direction and the particle will follow a circular trajectory hitting the screen 2 above the hole.

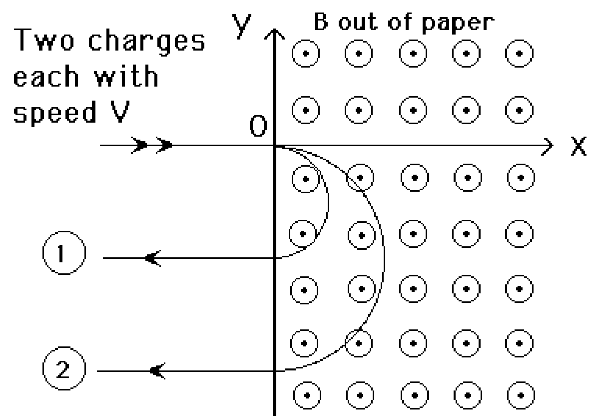
e) is constant in magnitude but changes direction and the particle will follow a circular trajectory hitting the screen 2 below the hole.

f) changes magnitude and direction and the particle will follow a curved trajectory hitting the screen 2 above the hole.

g) changes magnitude and direction and the particle will follow a curved trajectory hitting the screen 2 below the hole.

Problem 2:

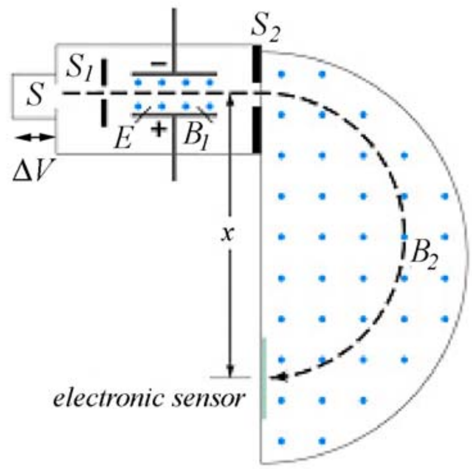
The entire x-y plane to the right of the origin O is filled with a uniform magnetic field of magnitude B pointing out of the page, as shown. Two charged particles travel along the negative x axis in the positive x direction, each with velocity $\vec{v}$, and enter the magnetic field at the origin O. The two particles have the same mass m, but have different charges, q_1 and q_2. When in the magnetic field, their trajectories both curve in the same direction (see sketch), but describe semi-circles with different radii. The radius of the semi-circle traced out by particle 2 is exactly twice as big as the radius of the semi-circle traced out by particle 1.



(a) Are the charges of these particles positive or negative? Explain your reasoning.

(b) What is the ratio q_2 / q_1?

Problem 3:
Shown below are the essentials of a commercial mass spectrometer. This device is used to measure the composition of gas samples, by measuring the abundance of species of different masses. An ion of mass m and charge $q = +e$ is produced in source S, a chamber in which a gas discharge is taking place. The initially stationary ion leaves S, is accelerated by a potential difference $\Delta V > 0$, and then enters a selector chamber, S_1, in which there is an adjustable magnetic field $\vec{\mathbf{B}}_1$, pointing out of the page and a deflecting electric field $\vec{\mathbf{E}}$, pointing from positive to negative plate. Only particles of a uniform velocity $\vec{\mathbf{v}}$ leave the selector. The emerging particles at S_2, enter a second magnetic field $\vec{\mathbf{B}}_2$, also pointing out of the page. The particle then moves in a semicircle, striking an electronic sensor at a distance x from the entry slit. Express your answers to the questions below in terms of $E \equiv \left|\vec{\mathbf{E}}\right|$, e, x, m, $B_2 \equiv \left|\vec{\mathbf{B}}_2\right|$, and ΔV.

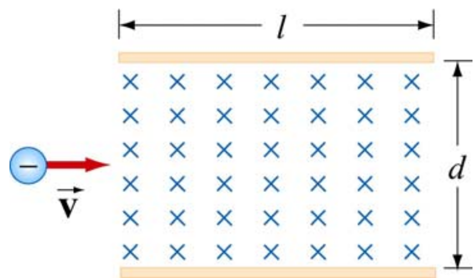


a) What magnetic field $\vec{\mathbf{B}}_1$ in the selector chamber is needed to insure that the particle travels straight through?

b) Find an expression for the mass of the particle after it has hit the electronic sensor at a distance x from the entry slit

Problem 4:

particle of charge $-e$ is moving with an initial velocity $\vec{\mathbf{v}}$ when it enters midway between two plates where there exists a uniform magnetic field pointing into the page, as shown in the figure below. You may ignore effects of the gravitational force.



(a) Is the trajectory of the particle deflected upward or downward?

(b) What is the magnitude of the velocity of the particle if it just strikes the end of the plate?

Problem 5:

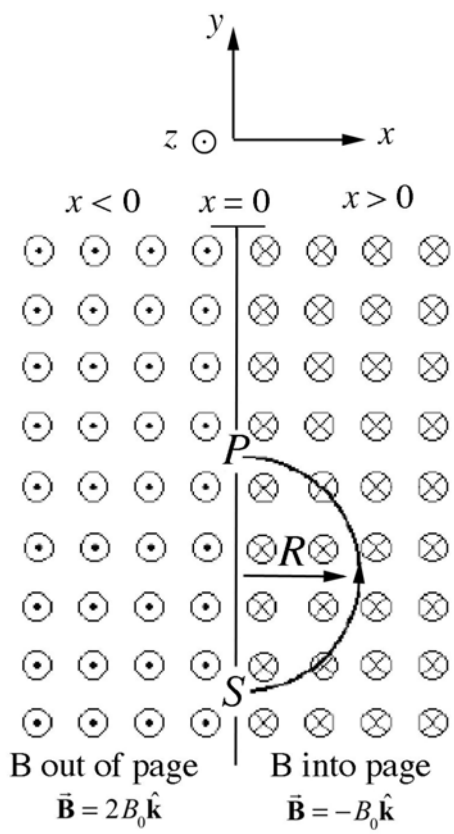
A copper wire of diameter d carries a current density $\vec{\mathbf{J}}$ at the earth's equator where the earth's magnetic field is horizontal, points north, and has magnitude $\left|\vec{\mathbf{B}}_{earth}\right| = 0.5\times10^{-4}\ \mathrm{T}$. The wire lies in a plane that is parallel to the surface of the earth and is oriented in the east-west direction. The density of copper is $\rho_{Cu} = 8.9\times10^{3}\ \mathrm{kg}\cdot\mathrm{m}^{-3}$. The resistivity of copper is $\rho_r = 1.7\times10^{-8}\,\Omega\cdot\mathrm{m}$.

a) How large must $\vec{\mathbf{J}}$ be, and which direction must it flow in order to levitate the wire? Use $g = 9.8\,\mathrm{m}\cdot\mathrm{s}^{-2}$

b) When the wire is floating how much power will be dissipated per cubic centimeter?

Problem 6:

The $x-y$ plane for $x<0$ is filled with a uniform magnetic field pointing out of the page, $\vec{\mathbf{B}} = 2B_0\,\hat{\mathbf{k}}$ with $B_0 > 0$, as shown. The $x-y$ plane for $x>0$ is filled with a uniform magnetic field $\vec{\mathbf{B}} = -B_0\,\hat{\mathbf{k}}$, pointing into the page, as shown. A charged particle with mass m and charge q is initially at the point S at $x=0$, moving in the positive x-direction with speed v. It subsequently moves counterclockwise in a circle of radius R, returning to $x=0$ at point P, a distance $2R$ from its initial position, as shown in the sketch.



a) Is the charge positive or negative? Briefly explain your reasoning.

b) Find an expression for the radius R of the trajectory shown, in terms of v, m, q, and B_0.

c) How long does the particle take to return to the plane $x = 0$ at point P?

d) Describe and sketch the subsequent trajectory of the particle on the figure below after it passes point P. Be sure to define any relevant distances in terms of v, m, q, and B_0.

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