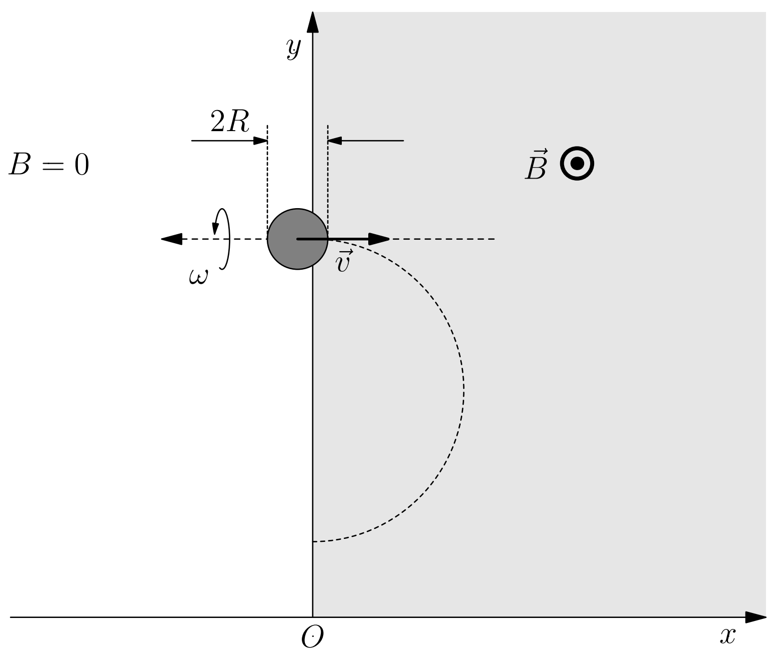
J04E.2—Mass Spectrometer

Problem

Let the magnetic field, $\boldsymbol{B}$, have the configuration which is used in mass spectrometers: $\boldsymbol{B} = 0$ for $x < 0$, while for $x > 0$ it is uniform, $\boldsymbol{B} = B_0\hat{\boldsymbol{z}}$. A spherical ball with radius R, total mass M and total charge Q approaches the plane $x = 0$ from the left and enters the magnetic field region $x > 0$ with center of mass velocity v in the x-direction. In addition, the ball rotates with angular velocity ω about the x-axis. The density of the ball is distributed uniformly throughout its volume.

The ball enters the region $x > 0$, spends there some time t and then leaves the region.

Both the speed v and angular velocity ω are small, so that relativistic effects can be neglected. The ball is so small that you can ignore all the rotational dynamics during the time $2R|v|$ when it traverses the boundary at $x = 0$.



a) Determine the time t the ball was subject to the magnetic field.

b) Assume that the charge of the ball Q is uniformly distributed throughout its volume, as the mass is, and evaluate the initial angular momentum and magnetic moment of the ball.

c) Determine the direction of the angular momentum after the ball comes back to the region where $\boldsymbol{B} = 0$.

d) Suppose instead that the charge Q were uniformly distributed over the *surface* of the ball, while the mass remains uniform throughout the *volume*. What is the initial magnetic moment? How is the final magnetic moment directed?