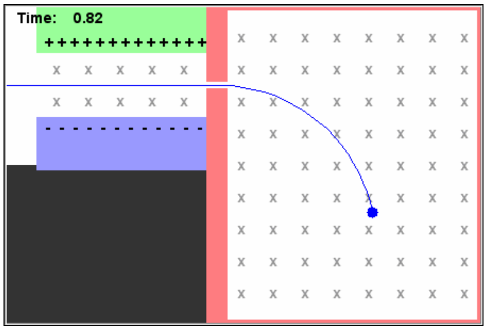
Worksheet for Exploration 27.3: Mass Spectrometer



A negatively charged particle enters a region with a constant magnetic field directed into the screen and a constant electric field produced by two charged plates. If the particle is able to pass through the first region, it enters a region where only the magnetic field is present. .

The Exploration demonstrates how a mass spectrometer works (See Illustration 23.4 and Exploration 25.4 for related examples). Many particles might be injected into the first region. For certain values of electric and magnetic fields only particles with a particular velocity will pass through undeflected. By subjecting the particles to the velocity selector, we know the velocity of the particle when it enters the second region.

a. If the initial velocity is 50 m/s, the magnetic field is 0.5 T, the mass is 0.3 g, and the charge is -1×10^{-3} Coulombs, what must the electric field be in order to "select" the 50 m/s particle? Calculate your answer first and then test it using the animation.

$E_{predicted}$=__________

$E_{measured}$=__________

b. If you change the value of the magnetic field, is the 50 m/s particle still "selected"?

c. What if you change the mass or the charge? Explain.

d. Once you are able to select the 50 m/s particle and it passes into a region where only the magnetic field is present, it follows a curved circular path. Why?
   i. Select a small mass, say about 0.1 so that after the mass passes through the opening it comes back and hits the same wall making a half circle.
   ii. You should be able to calculate the radius of the path by considering the magnetic force and equations describing circular motion.
   iii. Measure the radius of the circle to check your prediction.

Equation predicting r:

$r_{predicted\ (number)}$=__________

$r_{measured}$=__________

Now change the mass from 0.3 g to 0.1 g. Notice that the curved path of the charge changes. For every mass, the curved path will be slightly different. This allows you to measure the mass of an individual particle. This is very useful, especially when the mass is too small to easily measure using other methods.

e. By considering the magnetic force in the second region, develop a mathematical expression that relates the mass of the particle to the other variables. Do not include the velocity in your expression. You can use the condition that the particle passed through the region of electric and magnetic fields undeflected to eliminate v from your expression. Your expression will also contain the radius of the circular path.
   i. Your expression for m should depend on B, E, r, and q.

   m=________

You can measure this radius in the applet using a mouse-down **(position is given in meters and time is given in seconds)**. In a real mass spectrometer the radius is often measured by putting a photographic plate on the wall where the particle hits. When the particle hits the plate it leaves a mark, allowing the experimenter to determine the value of the radius.

f. Check the expression you derived. When you put in the values from above, do you get a mass of 0.1 gram as you should?

   $m_{predicted}$=_________

   $m_{measured}$=_________