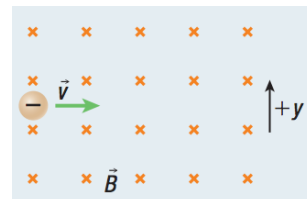




Unit 3 Chapter 8: Magnetic fields

Lesson 3.8: Motion of charged particles in magnetic Fields (8.4)

Example 1: An electron starts from rest. A horizontally directed electric field accelerates the electron through a potential difference of 37 V. The electron then leaves the electric field and moves into a magnetic field with strength of 0.26T, directed into the page.

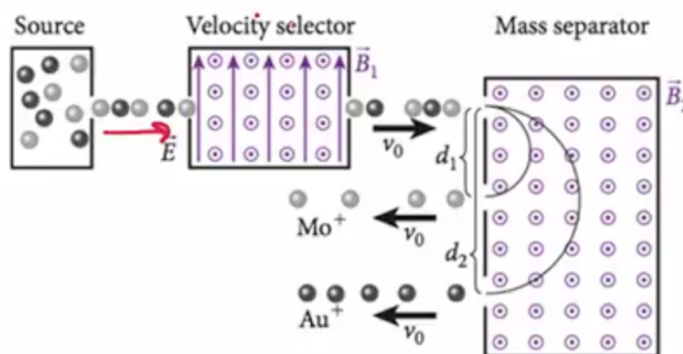


- Determine the speed of the electron at the moment it enters the magnetic field.
- Determine the magnitude and direction of the magnetic force on the electrons.
- Determine the radius of the electron's circular path.

Mass Spectrometers:

Mass spectrometers can be used to determine the mass-to-charge ratio of unknown substance or to separate similar compounds of slightly different mass.

First the sample is vaporized and then it is bombarded with electrons. These high energy electrons ionize the sample by knocking loose electrons. These cations are then accelerated by a potential difference and then fired into velocity selector, followed by a perpendicular magnetic field. This magnetic field causes them to bend until they strike a detector.



Questions:

- How can this be used to determine the mass of an unknown sample?
- In practice even a pure substance will strike the detector at multiple locations. Explain why this might occur?



Example 2:

A researcher using a mass spectrometer observes a particle travelling at 1.6×10^6 m/s in a circular path of radius 8.2 cm. The spectrometer's magnetic field is perpendicular to the particle's path and has a magnitude of 0.41 T.

- (a) Calculate the mass-to-charge ratio of the particle. (In 1910, Robert Millikan accurately determined the charge carried by an electron. His finding allowed researchers to calculate the mass of charged particles using the mass-to-charge ratio.)
- (b) Identify the particle using **Table 1**.

Table 1

Isotope	m (kg)	q (C)	$\frac{m}{q}$ (kg/C)
hydrogen	1.67×10^{-27}	1.60×10^{-19}	1.04×10^{-8}
deuterium	3.35×10^{-27}	1.60×10^{-19}	2.09×10^{-8}
tritium	5.01×10^{-27}	1.60×10^{-19}	3.13×10^{-8}

Practice 1: Mass spectrometers can also be used to separate substances into individual isotopes. For example uranium naturally exists as a mixture of U-238 and U-235, 238 is inert whereas 235 is highly radioactive. Describe how these two isotopes could be separated using a mass spectrometer.

Practice 2: A researcher uses a mass spectrometer in a carbon dating experiment. The incoming ions are a mixture of $^{12}\text{C}^+$ and $^{14}\text{C}^+$, and they have speed $v = 1.0 \times 10^5$ m/s. The strength of the magnetic field is 0.10 T. The mass of an electron is 9.11×10^{-31} kg, and the mass of protons and neutrons is 1.67×10^{-27} kg. The researcher first positions the ion detector to determine the value of radius for $^{12}\text{C}^+$, then moves it to determine the value of radius for $^{14}\text{C}^+$. How far must the detector move between detecting the two isotopes. (Textbook pg400)



Check this out – Mass Spectrometer simulation:

http://tutor-homework.com/Physics_Help/isotope_mass_spectrometer.html

Ionization Accelerating voltage applied Velocity selector Magnetic field region

After ionization, acceleration, and selection of single velocity particles, the ions move into a mass spectrometer region where the radius of the path and thus the position on the detector is a function of the mass.

Detector

$$r = \frac{mv}{qB} = \frac{mE_s}{qBB_s}$$

If a charge moves into a [magnetic field](#) with direction perpendicular to the field, it will follow a circular path. The [magnetic force](#), being perpendicular to the velocity, provides the [centripetal force](#).

$$r = \frac{mv^2}{qvB} = \frac{mv}{qB}$$

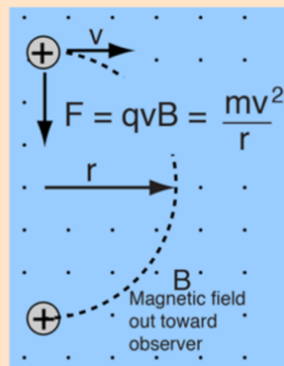
Radius of path produced by magnetic field

If the velocity v is produced by an accelerating voltage V :

$$\frac{1}{2}mv^2 = qV ; v = \sqrt{\frac{2qV}{m}}$$

Substitution gives:

$$r = \frac{1}{B} \sqrt{\frac{2mV}{q}}$$



Accelerated particles Magnetic force Undelected particles Selected velocity

From setting electric force equal to magnetic force

Too fast Too slow

$F_B = qvB$

$F_E = qE$

$v = \frac{E}{B}$

<http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/maspec.html>