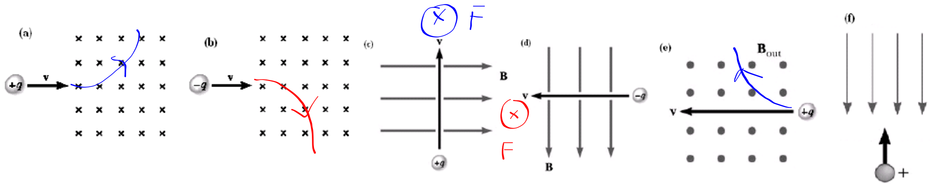
Find the direction of the magnetic force on each particle below as each enters the magnetic field shown.



Magnitude of the magnetic force on a moving charged particle:

$F = qvB \sin \theta$

$F = q\vec{v} \times \vec{B}$

Where θ is angle between v and B

Definition of magnitude of magnetic field (#2):

The ratio of the force on a charged particle moving in a magnetic field to the product of the particle's charge, velocity and sine of the angle between the direction of the magnetic field and velocity.

$B = \frac{F}{qv} \quad \left[\frac{N}{C\,m/s}\right] = [T]$

A proton in a particle accelerator has a speed of 5.0×10^6 m/s. The proton encounters a magnetic field whose magnitude is 0.40T and whose direction makes an angle of $\theta = 30.0°$ with respect to the proton's velocity. Find the magnitude of the magnetic force on the proton and the proton's acceleration. How would these change if the particle was an electron?

if $F \perp v$

$F = q\vec{v} \times \vec{B}$

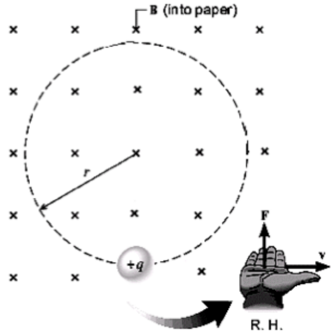
$= qvB \sin\theta$

$= 1.6 \times 10^{-19}\,C \; 5 \times 10^{6}\,m/s \; 0.4T \; \sin 30°$

$\sim 1.6 \times 10^{-13}\,N$

$a = \frac{F}{m} = \frac{1.6 \times 10^{-13}\,N}{1.67 \times 10^{-27}\,kg} \sim 9.6 \times 10^{13}\,m/s^2$

Motion of a Charged Particle in a Magnetic Field



1. A charged particle will follow a circular path in a magnetic field since the magnetic force is always perpendicular to the velocity.

2. The magnetic force does no work on the particle since the magnetic force is always perpendicular to the motion.

3. The particle accelerates centripetally but maintains a constant speed since the magnetic force does no work on it.

Radius of Circular Path

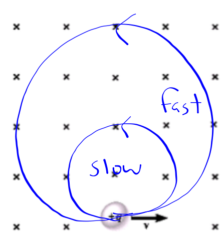
$$\Sigma F = m\frac{v^2}{r}$$

$$q\vec{v}\times\vec{B} = m\frac{v^2}{r}$$

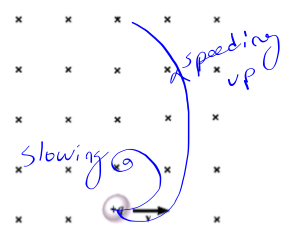
*know this

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

a) Sketch the paths of a slow and a fast moving proton at constant speed.



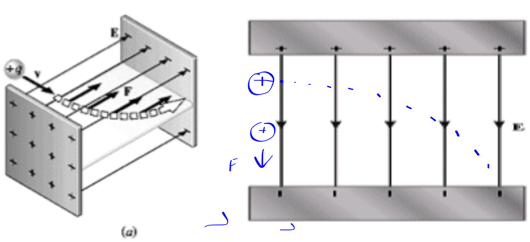
b) Sketch the path of a proton that is slowing down and one that is speeding up.



c) How would the radius of the path change if the particle were an alpha particle?

Comparing Electric and Magnetic Fields and Forces

Electric Field



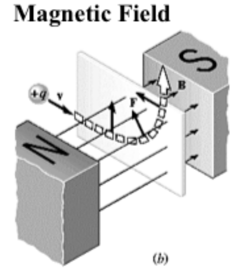
(a)

$\vec{F} \parallel \vec{E}$

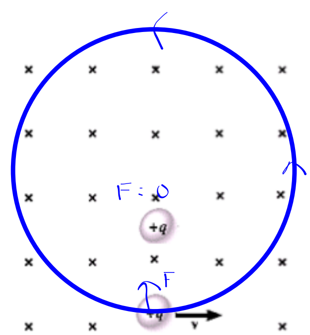
accl,

parabolic motion

Magnetic Field



(b)



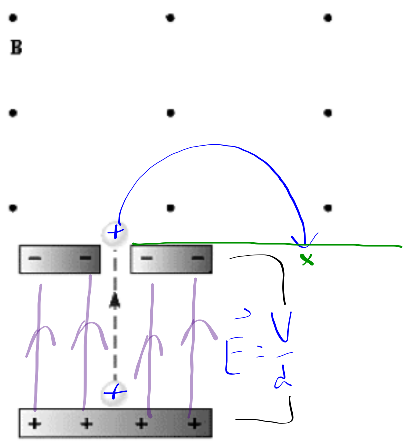
$F \perp \vec{B}$

accl inward

circ. motion

Electric Fields and Magnetic Fields

1. A proton is released from rest near the positive plate and leaves through a small hole in the negative plate where it enters a region of constant magnetic field of magnitude 0.10T. The electric potential difference between the plates is 2100 V.



a) Describe the motion of the proton while in the electric field

accl in straight line

b) Describe the motion of the proton while in the magnetic field

const accl inward, const. speed

c) Find the speed of the proton as it enters the magnetic field.

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

$= \sqrt{\frac{2\,(1.6\times10^{-19}\,C)(2100\,J/C)}{1.67\times10^{-27}\,kg}} = 6.3\times10^{5}\,m/s$

d) Find the radius of the circular path of the proton in the magnetic field.

$r = \frac{mv}{qB} = \frac{(1.67\times10^{-27}\,kg)(6.3\times10^{5}\,m/s)}{(1.6\times10^{-19}\,C)(0.1\,T)} = .066\,m$

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2. A **Velocity Selector** is a device for measuring the velocity of a charged particle. The device operates by applying electric and magnetic forces to the particle in such a way that these forces balance.

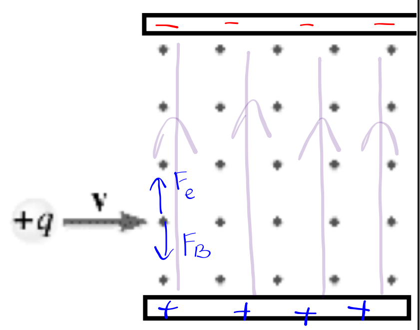
a) Determine the magnitude and direction of an electric field that will apply an electric force to balance the magnetic force on the proton.

$F_e = F_B$

$q\vec{E} = q\vec{v}\vec{B}$

*know this

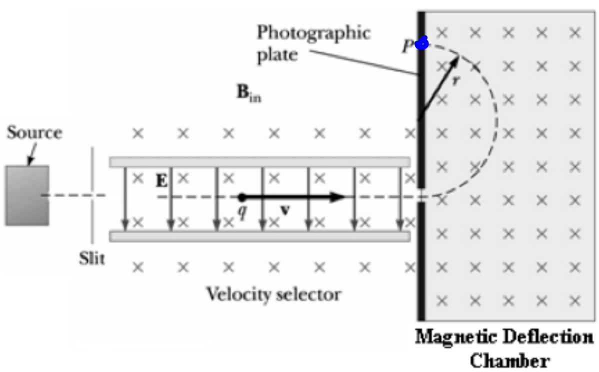
$v = \frac{\vec{E}}{\vec{B}}$



b) What is the resulting speed and trajectory of the proton?

The Mass Spectrometer

A **mass spectrometer** is a device used to measure the masses of isotopes. Isotopes of the same element have the same charge and chemical properties so they cannot be separated by using chemical reactions but have different masses and so can be separated by a magnetic field. A common type of mass spectrometer is known as the **Bainbridge mass spectrometer** and its main parts are shown below.



Ion Source: source of charged isotopes – same charge – different mass

Velocity selector: so all ions have the same speed

Magnetic deflection chamber: radius is proportional to mass

1. A singly charged ion with mass 2.18×10^{-26} kg moves without deflection through a region of crossed magnetic and electric fields then is injected into a region containing only a magnetic field, as shown in the diagram, where it is deflected until it hits a photographic plate. The electric field between the plates of the velocity selector is 950 V/m and the magnetic field in both regions is 0.930 T. Determine the sign of the charge and calculate where the ion lands on the photographic plate.

+

$$v = \frac{\vec{E}}{\vec{B}} = \frac{950\,V/m}{.93\,T} = 10^{3}\,m/s$$

$$r = \frac{mv}{qB} = \frac{2.18\times10^{-26}\,kg \;\; 10^{3}\,m/s}{1.6\times10^{-19}\,C \;\; 0.93\,T} = .15\,mm$$

$$d = .3\,mm$$

2. A hydrogen atom and a deuterium atom (an isotope of hydrogen) move out of the velocity selector and into the region of a constant 0.10 T magnetic field at point S, as shown below. Each has a speed of 1.0×10^{6} m/s. Calculate where they each hit the photographic plate at P.