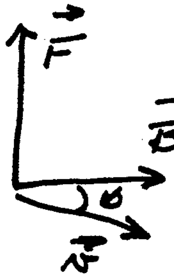
Magnetic Force



$$\vec F = q \, \vec v \times \vec B$$

$$= q v B \sin\phi$$

in direction ⊥ v and B

Right hand screw rule

For particle moving in $\vec B$ field since $F \perp v$ particle feels centripetal force

$B \perp v$ $\qquad R = \frac{mv}{Bq}$ circular orbit

B not $\perp v$

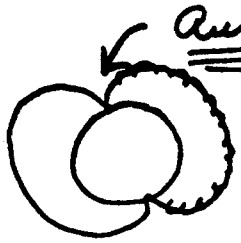
$$R = \frac{m v_\perp}{Bq}$$

get helical path 

Charged particles are constrained to move along lines of mag. field

Plasma - ionized gas. Fusion research
To get nuclei to interact must "confine" hot plasma. Magnetic bottle or "pinch".

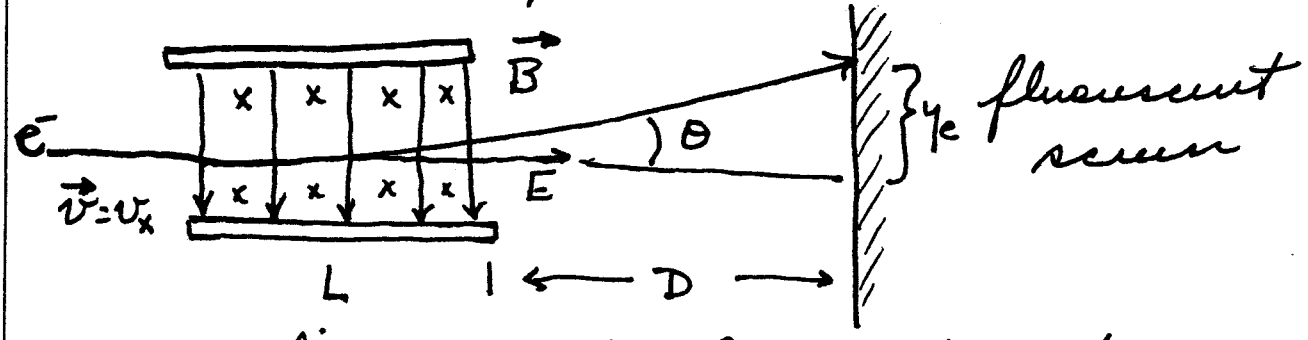
Earth's magnetosphere



Van Allen radiation belts: energetic particles confined to move along earth's magnetic field lines

Sometimes particles carry $\vec{B}$ field lines with them Solar Wind

Measurement of e/m (JJ Thomson 1897)



① E field due to charged // plates

$$F_y = eE = ma_y \Longrightarrow a_y = \frac{eE}{m}$$

$$v_y = a_y t = \left(\frac{eE}{m}\right)\frac{L}{v} = \frac{eEL}{mv} \quad \text{since } t = \frac{L}{v}$$

$$y_c = \tan\theta \left(D + \frac{L}{2}\right)$$

where $\tan\theta = \frac{v_y}{v_x} = \frac{eEL/mv}{v} = \frac{eEL}{mv^2}$

thus

$$y_e = \left(\frac{e}{m}\right)\frac{EL}{v^2}\left(D+\frac{L}{2}\right)$$

But $\vec{B}$ field will produce deflection in opposite direction

$$y_m = -\frac{eBL}{mv}\left(D+\frac{L}{2}\right)$$

If adjust B so that there is no net deflection

$$y_e + y_m = 0$$

$$\frac{e}{m}\frac{EL}{v^2}\left(D+\frac{L}{2}\right) = \frac{e}{m}\frac{BL}{v}\left(D+\frac{L}{2}\right)$$

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

Measure deflection in E field, use B to determine v

$$\frac{e}{m} = 1.758802 \pm .000005)\times 10^{11}\ \frac{C}{kg}$$

Combined w/ Millikan's expt $\Rightarrow$

$$m_e = 9.11\times 10^{-31}\ kg$$

Ability to measure q/m lead to discovery of isotopes

Nucleus

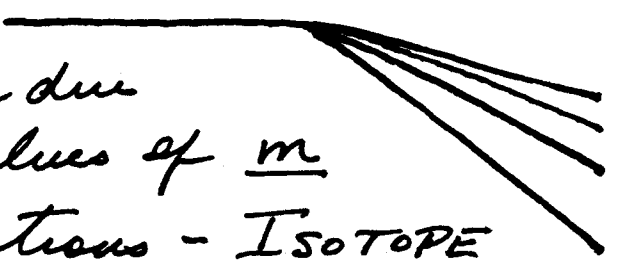
# of protons determines which element. Nucleus also contains neutral particles "neutrons"

typically $\#_n \sim \#_p$

Nucleus held together by nuclear forces.

Nucleus surrounded by cloud of electrons e^-. If $\#e^- = \#p^+$ atom is electrically neutral. Remove electron atom is positively charged - Ion

When looked at positive ions in Thomson expt found that ions of certain elements showed multiple deflections. Some due to diff't values of charge



Others must be due to different values of m

$\Rightarrow$ # of neutrons - ISOTOPE

$^{20}Ne \Rightarrow \begin{matrix} 10\,p^+ \\ 10\,n \end{matrix}$ $^{22}Ne \Rightarrow \begin{matrix} 10\,p^+ \\ 12\,n \end{matrix}$

Consider work done by $\vec{E}$ field

$$W = \int F_{\parallel} ds = qE \int_0^y ds$$

at any point y

$$W = qEy$$

Work done by $\vec{B}$ field $= 0$ $F_{\perp} ds$

Conservative force

$$KE = \frac{1}{2} mv^2 = qEy$$

$$v = \sqrt{\frac{2qEy}{m}}$$ at any point

Can think of this as superposition of two motions

At top of path $y = 2R$

$$F_{NET} = qvB - qE = \frac{mv_d^2}{R}$$

$$v_d = \frac{1}{2} v$$

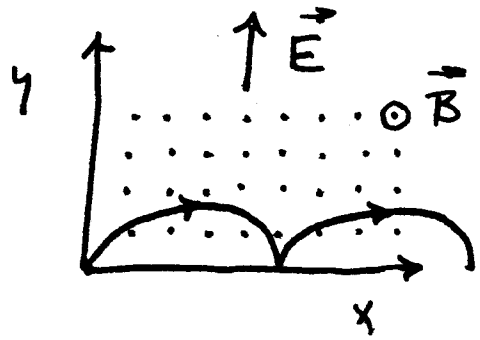
$$qvB - qE = \frac{\cancel{m}\left(\frac{2qE \cdot 2R}{\cancel{m}}\right)}{4R}$$

$$= qE$$

$$qvB = 2qE$$

$$v = \frac{2E}{B} \qquad v_d = \frac{E}{B}.$$

General case of crossed E B field for particle starting at rest

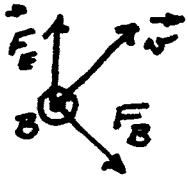


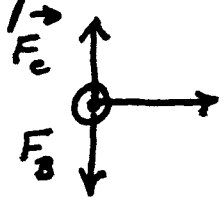
Initially $v = 0$

$F_E = qE \qquad F_B = 0$

$\Rightarrow$ particle accelerated to some velocity v; now have

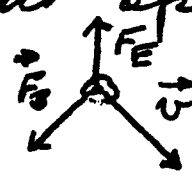
Particle will be deflected toward right





as v increases $\vec{F}_B$ increases, now $\vec{F}_B$ has component opposite to F_E

v_y decreases



F_B acts to decelerate particle will eventually come to rest