Chapter 28

The Magnetic Field

1. The Force Exerted by a Magnetic Field

- just like electric field $\vec{E}$

  magnetic field $\vec{B}$

- when a charge (q) has velocity (v) in a magnetic field, there is a force ~ q and to v and to the sine of the angle between $\vec{v}$ & $\vec{B}$.

  or $\vec{F} = q\vec{v} \times \vec{B} = qvB\sin\theta$

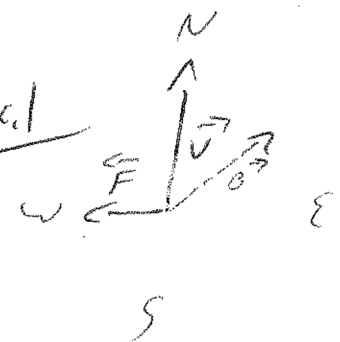
- Right hand Rule - fingers at $\vec{v}$ - curl toward $\vec{B}$ force in direction of thumb.

  $\vec{B}$ - measured in Teslas (T) $= 1 \frac{N/C}{m/s}$

  - a charge of 1 Coulomb moving w/ v 1m/s ⊥ to a mag. field of 1 T experience 1 N of Force.

Tesla very large - therefore - commonly use Gauss ($1G = 1\times10^{-4}T$)

ex. 1



$q = 1.6\times10^{-19}C$

$\vec{B} = .6G$ 70° into paper

$v = 1\times10^{7} m/s$

a) $F = qvB\sin 70° = 9.02\times10^{-17}N$

b) $\vec{v} = \cancel{0}\, V_y\,\hat{j}$

$\vec{B} = B_y\,\hat{j} + B_z\,\hat{k}$

$qv \times B$

$= \cancel{qV_y B_y(j\times j)} + qV_y B_z(j\times k)$

$B_z = -B\sin 70^\circ$

$\vec{F} = -9.02 \times 10^{-17} N\ \hat{i}$

- Wire - when a wire carries a current in a magnetic field, there is a force on the wire equal to the sum of the mag. forces on the charged particles whose motion produces current.

each particle $\underline{F = \vec{q}\vec{v}_0 \times \vec{B}}$

\# of charges in the wire segment

$= n \times \underbrace{A}_{\text{cross section Area}} \times l$ — length

n ← # charges per unit volume

$\vec{F} = nAl(q\vec{v}_0 \times \vec{B})$

$I = nqv_D A$ (from ch 26)

$\therefore\ \vec{F} = I\vec{l} \times \vec{B}$

or $\vec{F} = IlB\sin\theta$

$\vec{l}$ = vector of size length & direction of current.

- (assumed wire is straight & has uniform mag. field)

for any shape $d\vec{F} = \underbrace{I\,d\vec{l}}_{\text{current element.}} \times \vec{B}$

Magnetic Field lines - Just like electric field lines, except ① $\vec{E}$ are in direction of Electric force on a pos. charge.
$\vec{B}$ are $\perp$ to magnetic force on moving charge.
② $\vec{E}$ begin on ⊕ and end on ⊖.
$\vec{B}$ form close loops. - Do not begin or end.

see pg 859.

Ex. 2 3mm wire segment carries 3A in x dir.
$\vec{B} = .02T$ in xy plane $30°$ w/ x axis

$$\vec{F} = (3A)(.003m)(.02T)(\sin 30°) = 9\times10^{-5}N\ \hat{k}$$

Ex 3 Wire bent in semicircular loop in xy plane
- Carries current I. $\vec{B} = B\vec{k}$

$$F_{NET} = \int I d\ell \times dB$$

$$d\ell = -d\ell \sin\theta i + d\ell \cos\theta j$$

$$F = 2IRBj$$

Assignment #1 1, 3, 5, 6, 7, 10, 11, 13

28-2 Motion of a Pt Charge in a Mag. Field.

F always $\perp$ V $\therefore$ only changes direction.
does no W or ΔKE.

if $V \perp \vec{B}$ - motion is circular

$$F_M = qVB \sin 90 = qVB$$
$$F_c = \frac{mv^2}{r}$$
$$\frac{mv^2}{r} = qvB \qquad r = \frac{mv}{qB}$$

$$T = \frac{2\pi r}{v} \left(\frac{qB}{v}\right) = \frac{2\pi m\cancel{v}}{\cancel{v}(qB)} = \frac{2\pi m}{qB}$$

<u>cyclotron period</u>

$$f = \frac{1}{T} \quad \frac{qB}{2\pi m}$$

cyclotron frequency.

depend on q/m, not v or r

if v ~~has horizontal~~ not $\perp$, helix path

Note T & f depend on q/m ratio
not on r or v.

-If a charged particle is not $\perp$, we can resolve v into component parallel & $\perp$. Parallel is unaffected, $\perp$ is treated as above. $\therefore$ Helix.

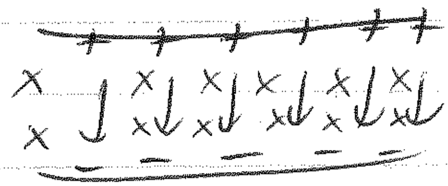
Velocity Selector -

Crossed Fields - A region where the electric field is balanced by a magnetic field.

$\vec{F_e}$ in direction of $\vec{E}$.

$\vec{F_m}$ $\perp$ to $\vec{B}$

$\therefore$ $\vec{E} \perp \vec{B}$



$\vec{E}$ $\vec{B}$ into paper
so $\vec{F_m}$ $\uparrow$

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

balanced if $\vec{F} = 0$ or $q\vec{E} = qv\vec{B}$
or $v = \frac{E}{B}$

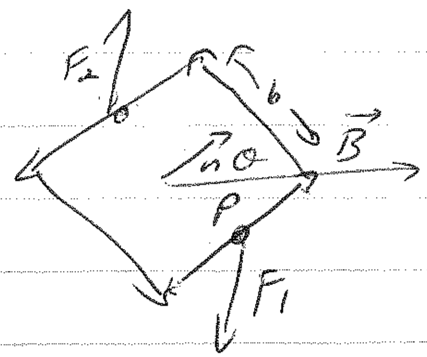
- $v > \frac{E}{B}$ deflected in direction of $\vec{B}$
- $v < E/B$ deflected in direction of $\vec{E}$

Read Mass spect. & cyclotron

28-3 Torque on Current Loops & Magnets.

$F_1 = F_2 = IaB$

For current carrying loop w/ normal at angle θ to $\vec{B}$.



Compute Torque around pt. P.

$\tau = F_2 b \sin\theta = IaBb \sin\theta = IAB \sin\theta$

A = area of loop.

if N turns.

$\tau = NIAB \sin\theta$.

twists so that $\hat{n}$ aligns w/ $\vec{B}$.

$\vec{\mu}$ = magnetic dipole moment $NIA\hat{n}$ (Am^2)

$\tau = \vec{\mu} \times \vec{B} = \mu B \sin\theta$

holds true for any loop of any shape

41, 42 & 43, 44

Torque on Current Loops & Magnets -

- A current carrying loop experiences no net force in a uniform magnetic field.
  - does experience a torque that twists it.
    - right hand rule gives orientation $\hat{n}$

$\hat{n}$ is at an angle θ w/ $\vec{B}$

$$\tau = IAB\sin\theta$$

I = current

A = area

B = magnetic field strength

for a loop w/ N turns

$$\tau = NIAB\sin\theta$$

$\vec{\mu} = NIA\hat{n}$ " magnetic dipole moment.

$$\tau = \vec{\mu} \times \vec{B}$$