(1)

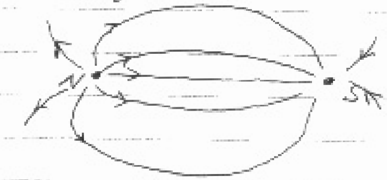
Magnetism

- known a long time
  - ~~stone~~ magnetite attracts pieces of iron
  - compass needle directionality
    - ↳ so have N + S poles
      - like + and - charges but we never see a 'monopole'
- 1802, Gian Romognosi
  - electric current in a wire deflects a nearby compass needle
    - ∴ a close relationship between electricity + magnetism
- later observation: move a magnet near a circuit + induce a current

(2)

Magnetic Fields

Think of similarly to $\vec{E}$ field



- field lines away from N poles

from moving charges,

$\vec{F}_B \propto q, v_q$

$\vec{F} \propto \vec{v}_q, \vec{B}$

→ when $\vec{v} \parallel \vec{B}$, $\vec{F}_B = 0$ on particle

$\vec{F}_B = q\vec{v} \times \vec{B}$ $\quad |\vec{F}_B| = |q| v B \sin\theta$

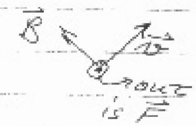
$\vec{F}_B \perp \vec{v} + \perp \vec{B}$

Right-hand screw rule:

→ fingers in $\vec{v}$ direction

→ fold toward $\vec{B}$ direction

→ direction of thumb → $\vec{F}$ direction



$\vec{E}$ vs $\vec{B}$

$\vec{F}_E \parallel \vec{E}$, $\vec{F}_B \perp \vec{B}$

$\vec{F}_B$ only acts when charge in motion

$\vec{F}_B$ does no work when steady field acts on particle
→ because $\vec{F}_B \perp$ displacement
∴ can only change direction, not kinetic energy

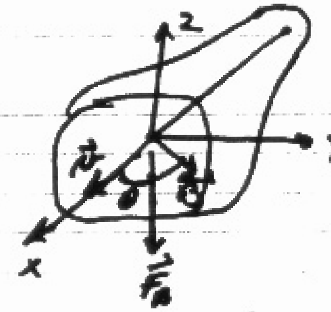
$$1\,\text{Tesla}\,(T) = 1\,\frac{N}{C \cdot m/s}$$
$$= 1\,\frac{N}{A \cdot m}$$

Ex 29.1

$\theta = 60^\circ$

$\vec{v}_e = 8 \times 10^6\,m/s\ \hat{i}$

$|\vec{B}| = \underline{0.025\,T}$



a) what is magnetic force on electron

$$F_B = |q|\,v B \sin\theta$$
$$= (1.6 \times 10^{-19}\,C)(8.0 \times 10^6\,m/s)(0.025\,T)\sin 60^\circ$$
$$= \underline{2.8 \times 10^{-14}\,N}$$

$\vec{v} \times \vec{B}$ means $\vec{F}_B$ in $-ve$ z direction (for $-ve$ q)

b) vector expressions

$\vec{v}_e = (8\times10^6\,\hat{i})$ m/s

$\vec{B} = (0.025\cos60^\circ\,\hat{i} + 0.025\sin60^\circ\,\hat{j})$ T

$= (0.013\,\hat{i} + 0.022\,\hat{j})$ T

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

$= -e\left[8\times10^6\,\hat{i}\,(\mathrm{m/s}) \times 0.013\,\hat{i}\,(\mathrm{T}) + 8\times10^6\,\hat{i}\,(\mathrm{m/s}) \times 0.022\,\hat{j}\,(\mathrm{T})\right]$

$\hat{i}\times\hat{i} = 0$

$\hat{i}\times\hat{j} = \hat{k}$

$= -e\left[(8\times10^6\,\mathrm{m/s})(0.022\,\mathrm{T})\right]\hat{k}$

$= \boxed{-2.8\times10^{-14}\,\mathrm{N}\,\hat{k}}$

wire segment, length L, cross-sectional area A

→ has current I

→ embedded in uniform $\vec{B}$

$\vec{F}_B$ on q is $q\vec{v}_d \times \vec{B}$

→ do for all charges in segment

nAL

n = #/volume

$\vec{F}_B^{TOT} = (q\vec{v}_d \times \vec{B})\,nAL$

$I = nqv_dA \rightarrow \vec{F}_B^{TOT} = I\vec{L}\times\vec{B}$ (straight wire)

$\vec{L}$ is vector in dir. of current I

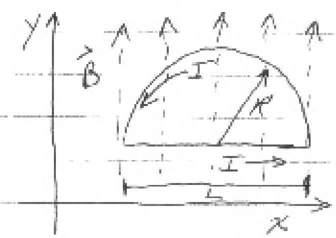
→ more generally, does not depend on shape of wire

→ if wire is closed loop

$\rightarrow \vec{F}_B = 0$

(2)

Ex. 29.2



$F_{straight}\ (F_1) = I\vec{L}' \times \vec{B}$

$= \underline{\underline{+ILB\,\hat{k}}}$ (out of page)

$\vec{F}_{curve}\ (F_2) = I\vec{L}'' \times \vec{B}$

→ but need to do look @ dF from dl

$dF_2 = IB\,dL = IB\,(R\,d\theta)$

$\underline{F_2} = \int_0^{\pi} dF_2 \sin\theta = IBR \int_0^{\pi} \sin\theta\, d\theta$

$= IBR\left[\cos\pi - \cos 0\right] = -2IBR \quad \left(\begin{smallmatrix}2R\\ =L\end{smallmatrix}\right)$

$= \underline{\underline{-IBL}}$ (into page)

$\vec{F}_{TOT} = \vec{F}_1 + \vec{F}_2$

$= \underline{\underline{0}}$

* Force on a current loop is 0 N.