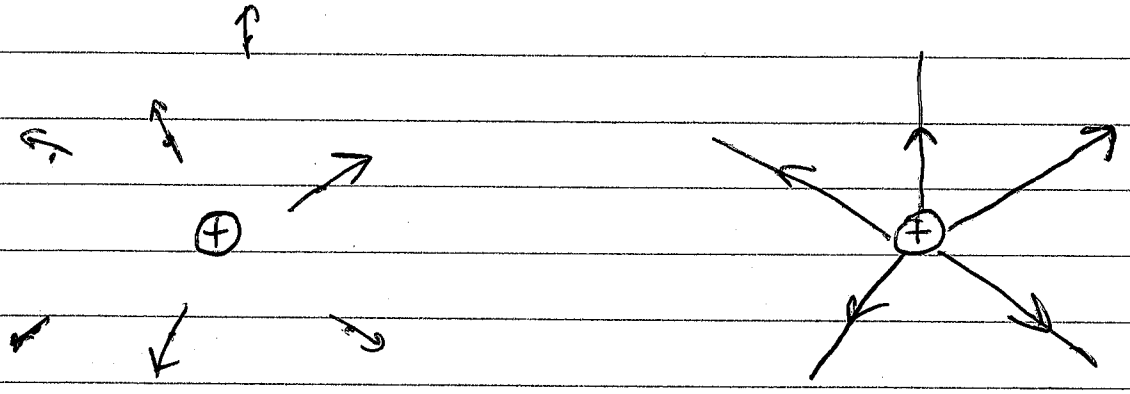
 Phys 2426 2016-09-29 Lec 11

Recall Electric Fields



$\vec{E}$ points away.

$$\vec{E} = \frac{kq_1}{r^2}\hat{r}$$

$\hat{r}$ "away"

E-Field Lines.
- Start at ⊕
- End at ⊖
- Never cross.
- Never loop.

Elec Field created by source charges
Elec Field affects other charges.

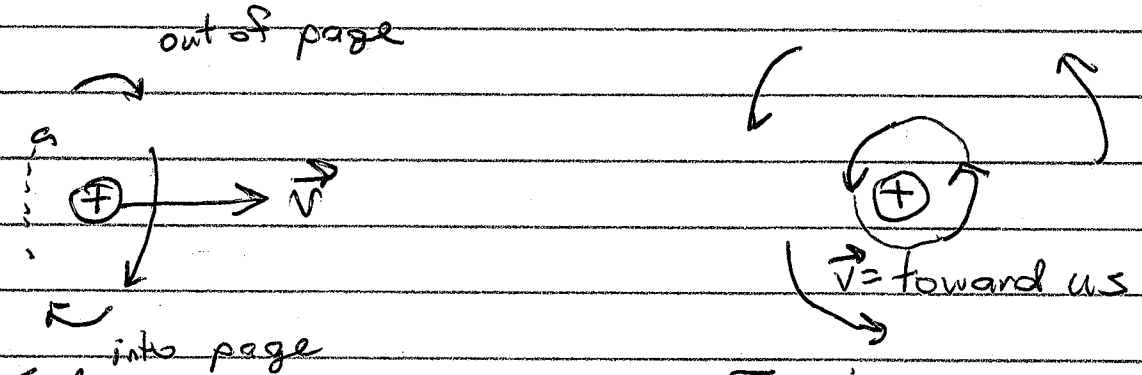
Magnetic Fields caused by
- Flowing conductive fluid (Earth)
- Currents (Electromagnets)
- Magnetic material

} Moving Charges

Magnetic Fields cause:
- Forces
- Torques
- Generate Voltage

} on other moving charges

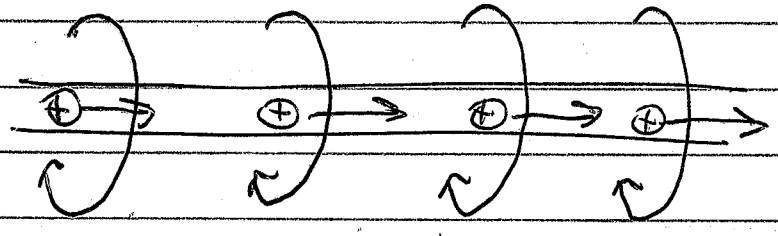
Simplest case: Moving charge



Side View Front View

Moving charge "stirs" magnetism.

A more realistic situation is a current:



There are so many charges, we don't see the "blips" of each one.

Can calculate with Riemann sum (Integral)

Magnetic Field ($\vec{B}$) measured in teslas (T)

- 50 μT typical Earth mag field.
- 1.0 T neodymium magnets
- 10 T NMR, MRI

Biot-Savart Law

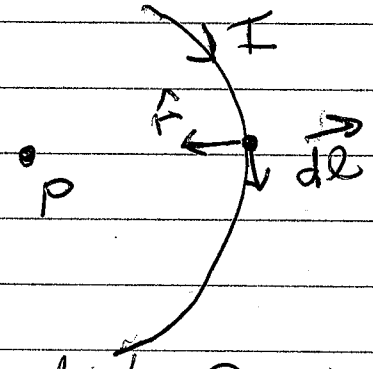
$$\vec{B} = \int d\vec{B} = \frac{\mu_0 I}{4\pi} \int \frac{d\vec{\ell} \otimes \hat{r}}{r^2}$$

Little contributions

Line integral

$d\vec{\ell}$ = part of the line or curve
$\hat{r}$ = dir from line to our point
r^2 = dist sqr from line to our point
$\otimes$ = cross product

For a circular Loop, our point @ center
(Ex 30.2 in Serway/Jewett)



$d\vec{\ell} \otimes \hat{r}$ is into page

Cross product Right-hand Rule

Ex: $\vec{\tau} = \vec{r} \otimes \vec{F}$

$\vec{B} \propto (d\vec{\ell} \otimes \hat{r}) = d\vec{\ell} \otimes \hat{r}$

Thumb — Index Finger — Middle Finger

$$\vec{B} = \frac{\mu_0 I}{4\pi r^2}\left[\int dl\right] \text{ (into page)}$$

$\int dl$ = Length of path

For full loop, $l = 2\pi r$

$$\vec{B} = \frac{\mu I}{2 \cancel{4\pi r^2}} (\cancel{2\pi r}) \text{ (into page)}$$

$$B = \frac{\mu I}{2r}$$ Field of a loop

$$B = \frac{\mu_0 I N}{2R}$$ Field of a coil

$\mu_0 = 4\pi \times 10^{-7}$ T·m/A

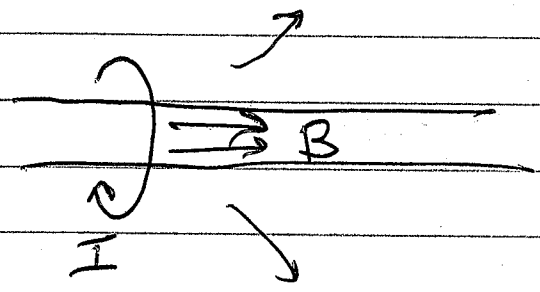
$(\pi 4E-7)$

For a straight current: (Ex 30.1)

$$B = \frac{\mu_0 I}{2\pi R}$$ Field of straight current

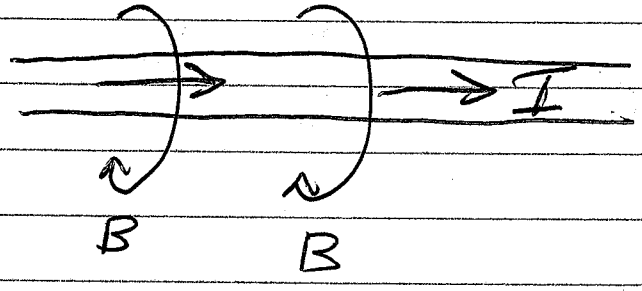
R = our dist from center of wire

RHR for coil:



- Curl fingers w/ I
- Thumb gives $\vec{B}$ inside the coil

RHR for straight current:



- Thumb along I
- Fingers curl with $\vec{B}$

Magnetic Field Lines

- Follow $\vec{B}$ vectors
- Never start or end; always loop.
- Never cross
- Skew to current
  (Not parallel, not toward/away)

Coordinate systems

+x	-x	+y	-y	+z	-z
Right	Left	Up	Down	Toward	Away
E	W	N	S	Up	Down