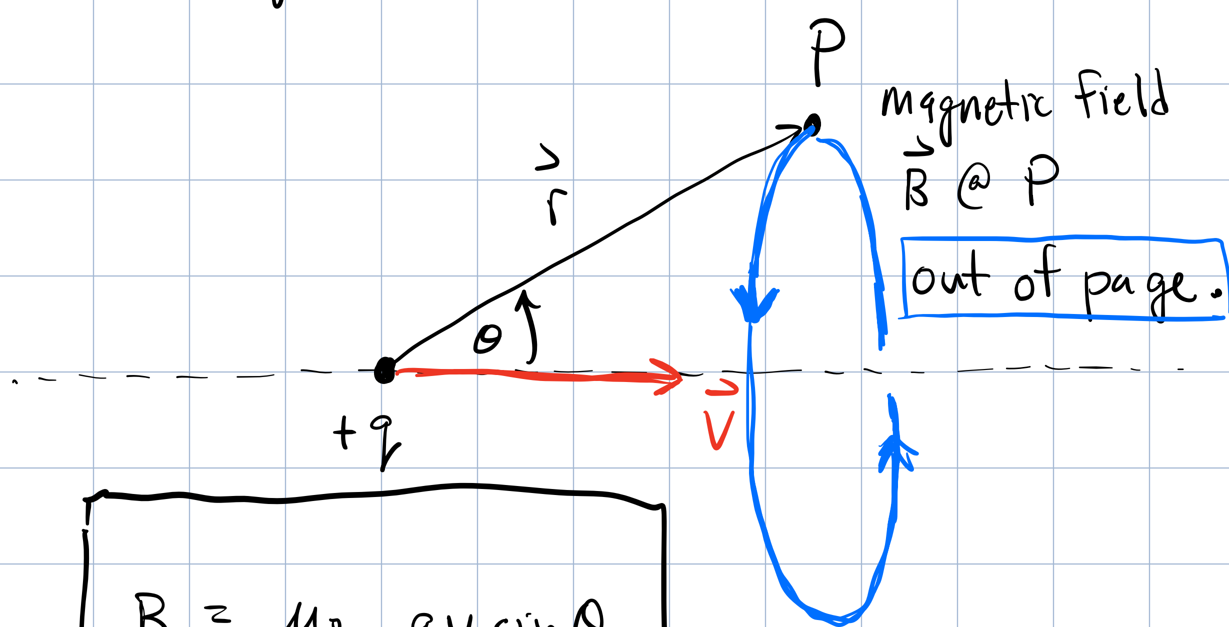
PHYS 121 March 18, 2024

- The next PrairieLearn HW is due Fri., Mar. 29
- Complete Pre-Lab #7 before the start of Lab #7
- Quiz #2 will be on Wednesday, March 20
  - ⇒ See course website for details.

Last Time:

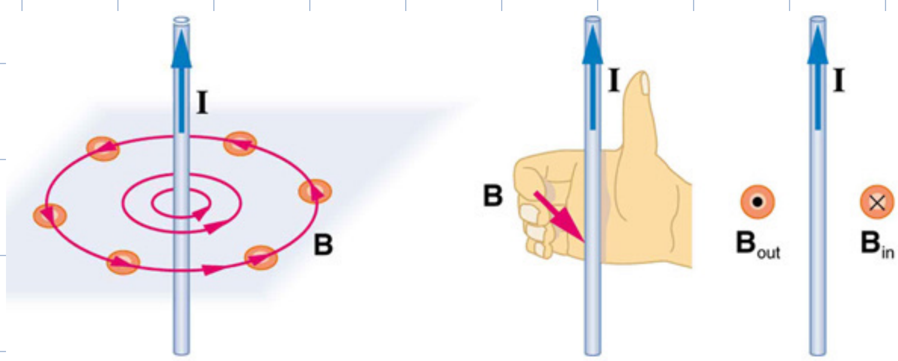
Magnitude of magnetic field due to moving pt. charge



$$\boxed{B = \frac{\mu_0}{4\pi} \frac{qv \sin\theta}{r^2}}$$

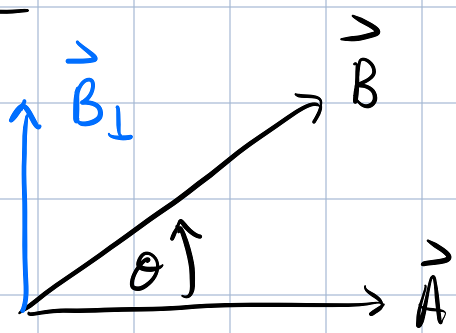
dir'n of $\vec{B}$ is given by RHR:

- Put thumb of right hand in dir'n of current (or dir'n of motion of positive charge)
- Fingers curl in dir'n of $\vec{B}$



Cross Product

Result of cross product is another vector:



$$\vec{C} = \vec{A} \times \vec{B}$$

In this example, $\vec{C}$ is $\boxed{\text{out of the screen}}$

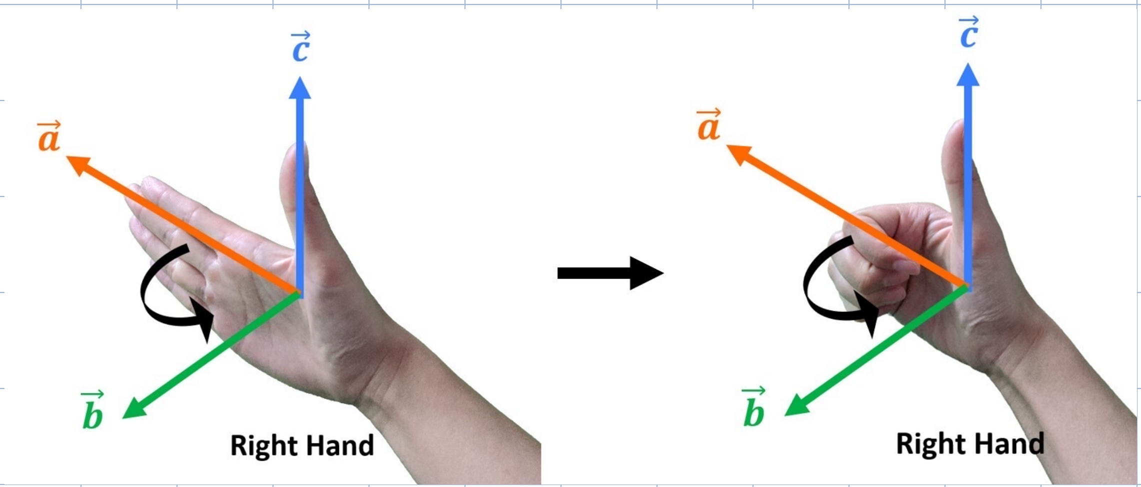
$\vec{C}$ is $\perp$ to both $\vec{A}$ & $\vec{B}$.

Magnitude of $\vec{C} = \vec{A} \times \vec{B}$:

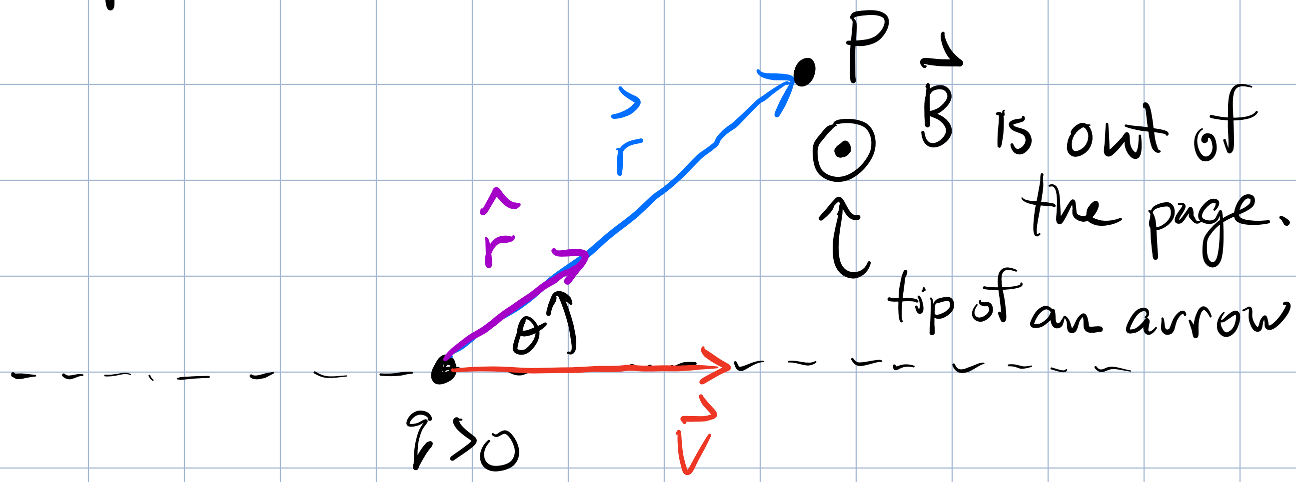
$$|\vec{C}| = C = AB \sin\theta$$
$$= AB_{\perp}$$

Dir'n of $\vec{C}$ (into or out of screen) is determined by another RHR:

- Place right hand/arm in dir'n of $\vec{A}$ (the first vector in the cross product)
- Curl fingers of right hand so that they are parallel to $\vec{B}$ (second vector in the cross product)
- Thumb points in the dir'n of $\vec{C}$.



Return to moving pt charge creating magnetic field @ P.



$\hat{r}$ is a unit vector $(|\hat{r}| = 1)$ in dir'n of $\vec{r}$

$$\vec{r} = r\,\hat{r}$$

Consider the cross product $\vec{v} \times \hat{r}$

Magnitude: $|\vec{v} \times \hat{r}| = \underbrace{|\vec{v}|}_{v}\underbrace{|\hat{r}|}_{1} \sin\theta$

$$= \boxed{v \sin\theta}$$

Note that $B = \dfrac{\mu_0}{4\pi} \dfrac{q\,\boxed{v \sin\theta}}{r^2}$

Dir'n of $\vec{v} \times \hat{r}$ is given by RHR & is out of the screen.

$\odot$ Represents out of the page (arrow tip)

$\otimes$ P Represents into the page (back or feathers of an arrow)

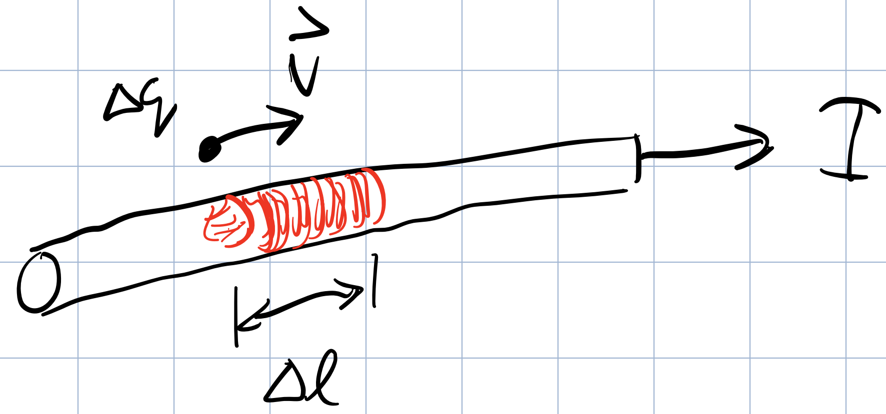
$\vec{v} \times \hat{r} =$ $v\sin\theta$ out of the page, same dir'n as $\vec{B}$.

Complete vector eq'n for $\vec{B}$ due to a moving point charge is:

$$\boxed{\vec{B} = \frac{\mu_0}{4\pi} \frac{q\,\vec{v} \times \hat{r}}{r^2}} \qquad (1)$$

Gives mag. & dir'n of $\vec{B}$.

Want to re-express ① in terms of a current.



The current can be expressed as

$$I = \frac{\Delta q}{\Delta t}$$

Mult. by $1 = \frac{\Delta l}{\Delta l}$

$$I = \frac{\Delta q}{\Delta t}\frac{\Delta l}{\Delta l} = \frac{\Delta q}{\Delta l}\underbrace{\frac{\Delta l}{\Delta t}}_{v}$$

$\therefore$ $I = \frac{\Delta q\, v}{\Delta l}$ solve for $\Delta q\, v$

$$\Delta q\, v = I\, \Delta l$$

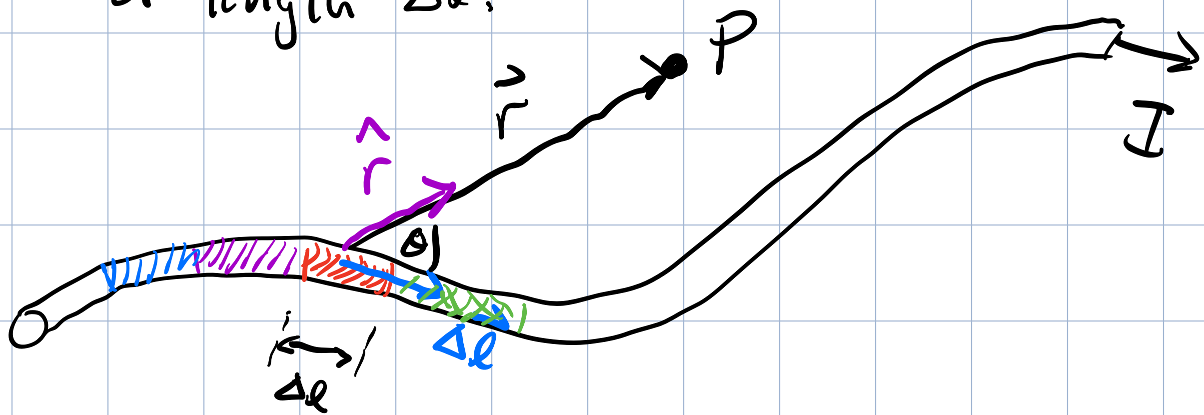
To make this a vector eq'n, we assign a dir'n to Δl. Define $\vec{\Delta l}$ s.t. its dir'n is parallel to current I.

$$\Delta q\, \vec{v} = I\, \vec{\Delta l}$$ sub this into ①.

Eq'n ① $$\vec{B} = \frac{\mu_0}{4\pi} \frac{q\, \vec{v} \times \hat{r}}{r^2}$$

$$\boxed{\therefore\ \vec{B} = \frac{\mu_0}{4\pi} \frac{I\, \vec{\Delta l} \times \hat{r}}{r^2}}$$ ②

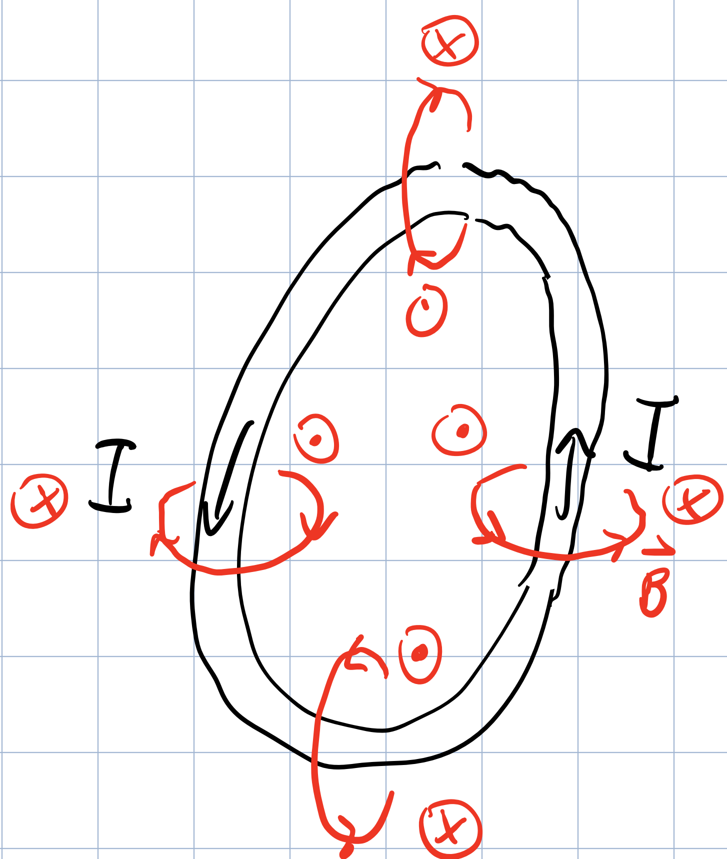
Biot-Savart Law – gives the magnetic field at pt. P due to current segment of length Δl.



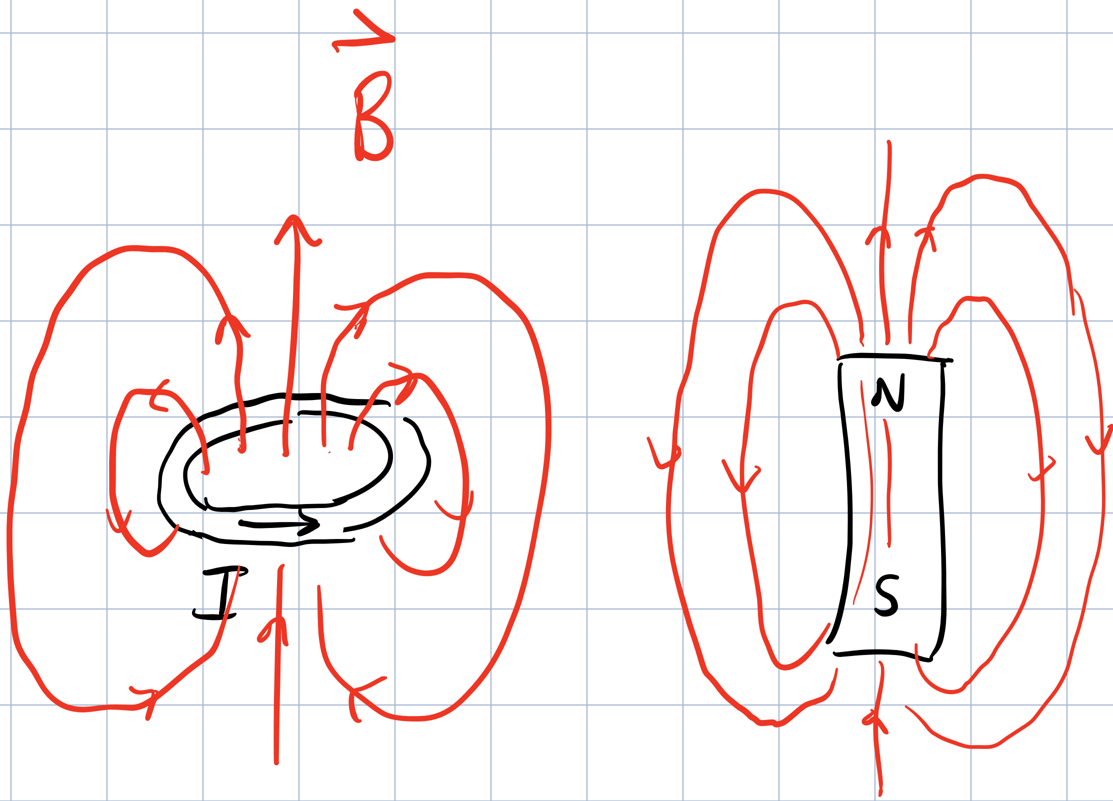
Eq'n ② gives $\vec{B}$ due to just the red coloured segment of the wire. To find the net $\vec{B}$ due to entire current in the wire, have to add up contributions from all segments.

Lab # 7

Consider a loop of current

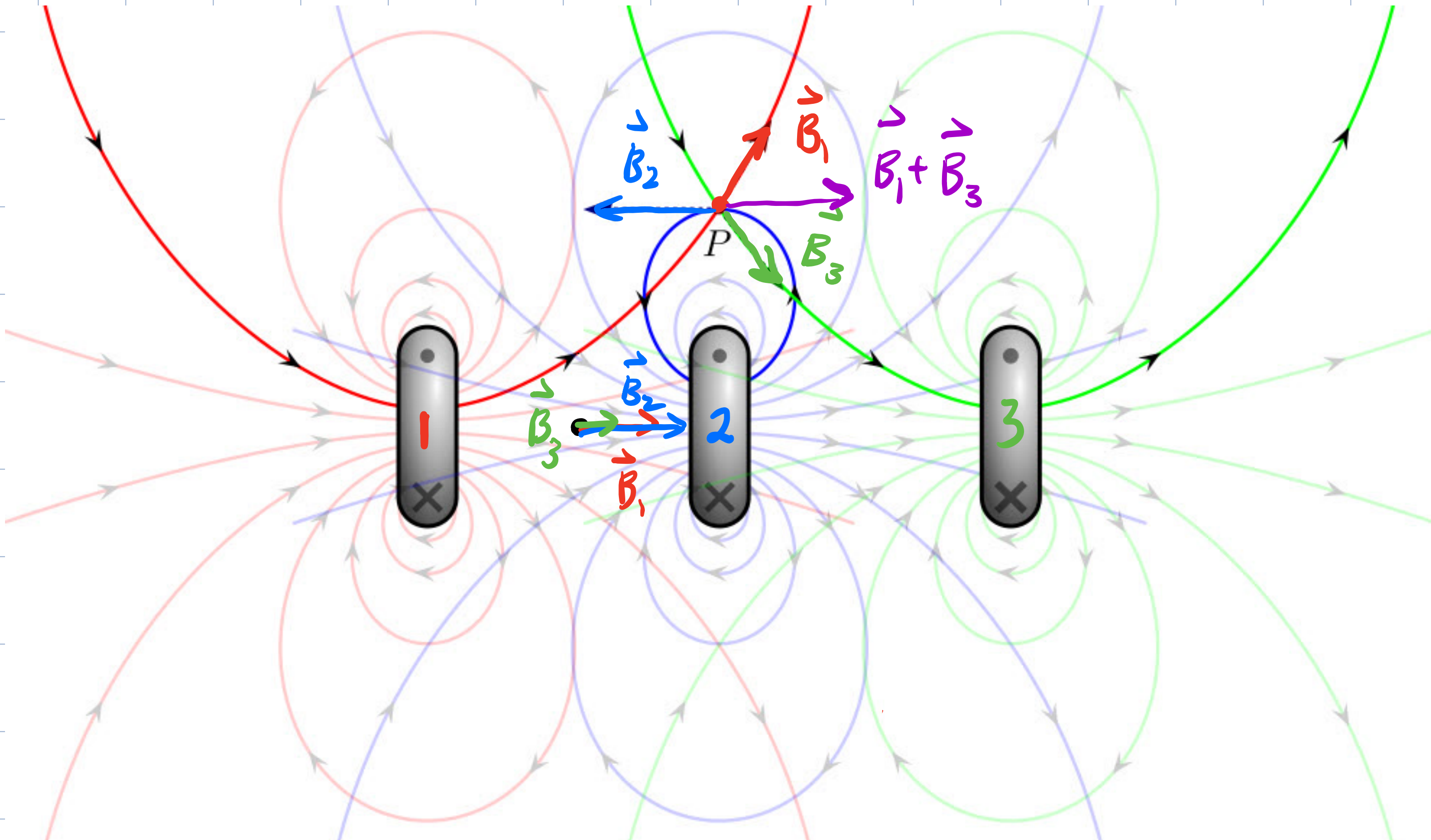


$\vec{B}$ is always in same dir'n inside loop, get strong field.



A current loop creates a magnetic field similar to that of a bar magnet.

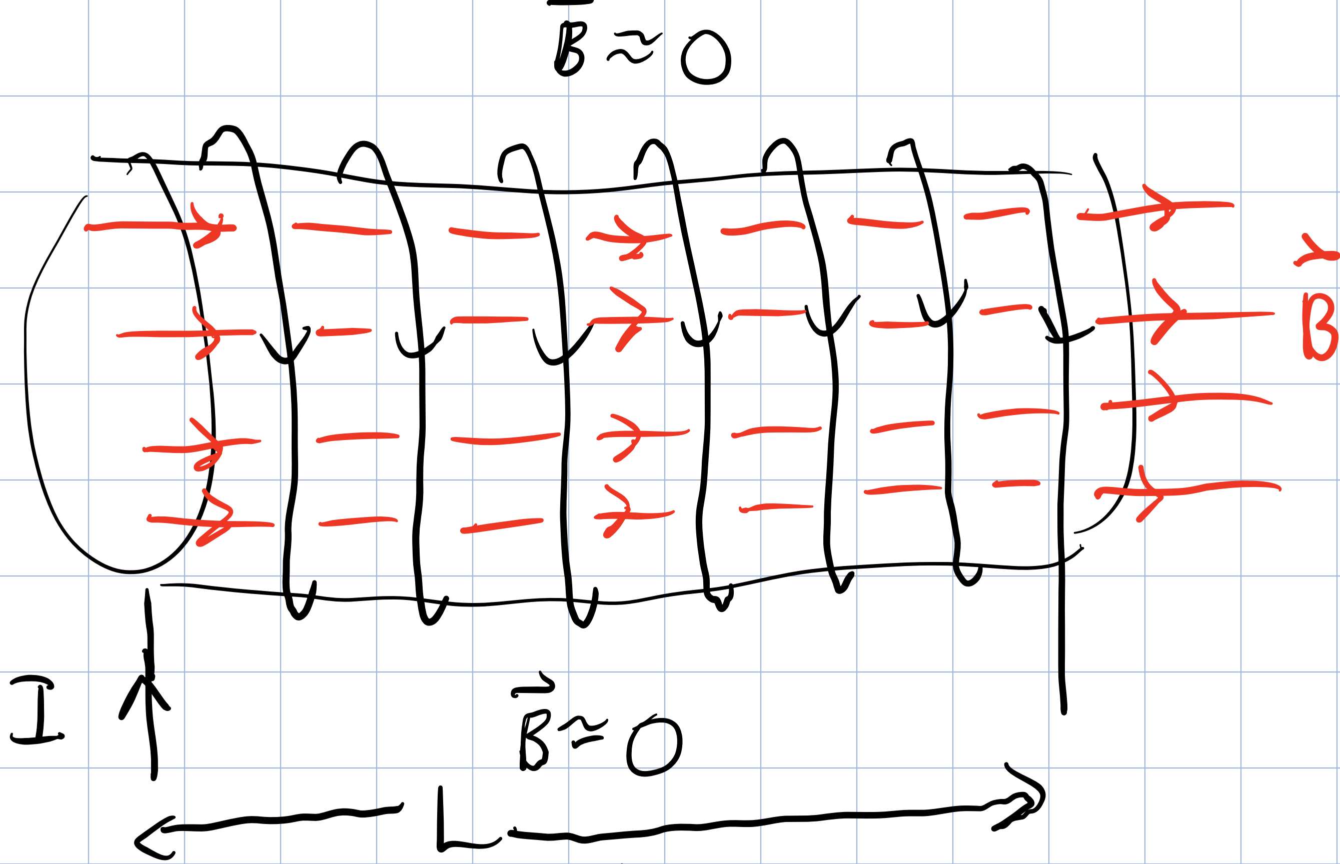
Consider placing a collection of current loops side-by-side.



To this series of current loops $\vec{B} \approx 0$ outside the loops/rings.

Inside the loops, the contributions to $\vec{B}$ all add up.

To mimic this situation, we can wind a coil of wire.



Similar to a collection of currents loops.

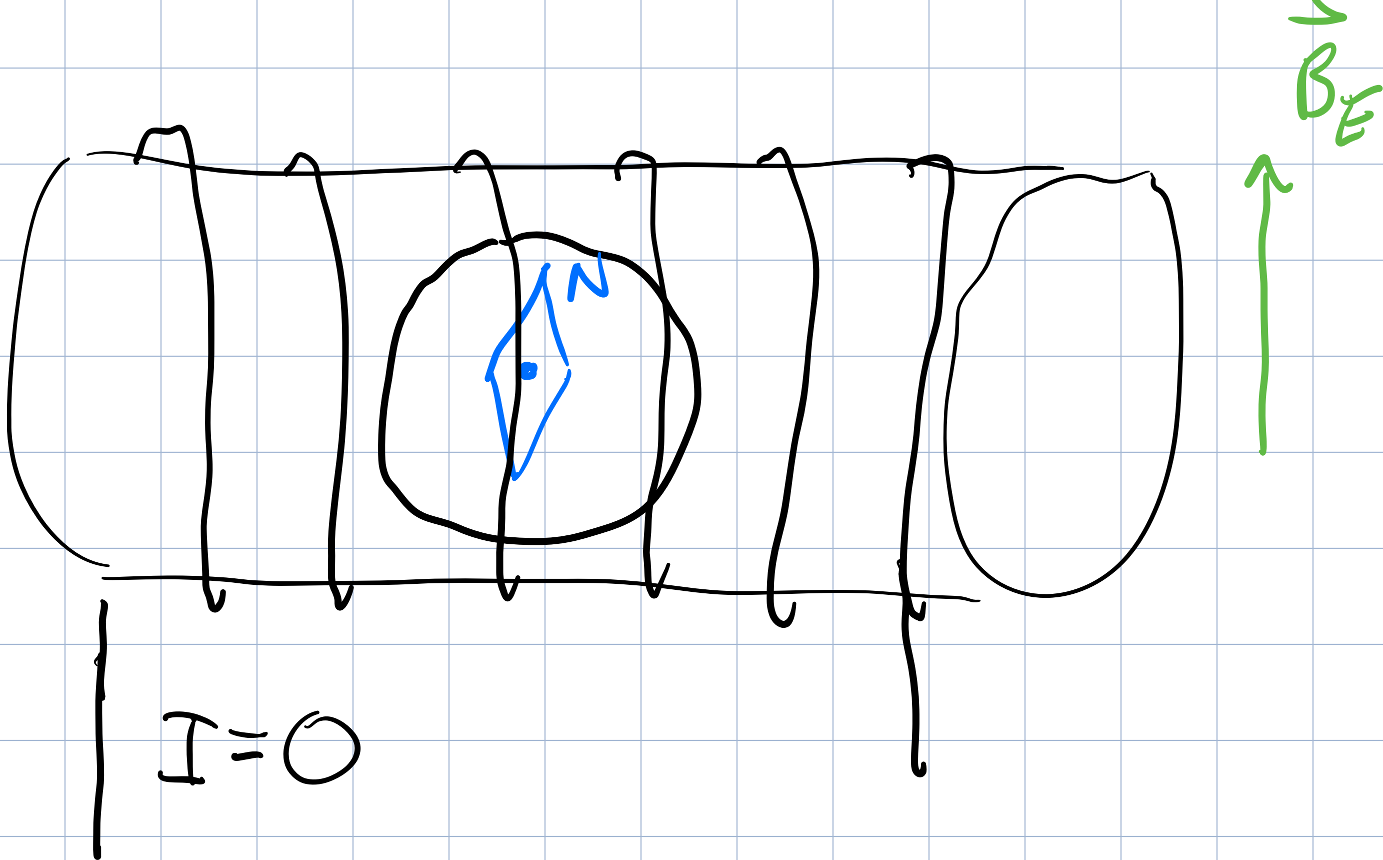
This coil of wire w/ current I is called a solenoid. It creates a uniform magnetic field inside its bore.

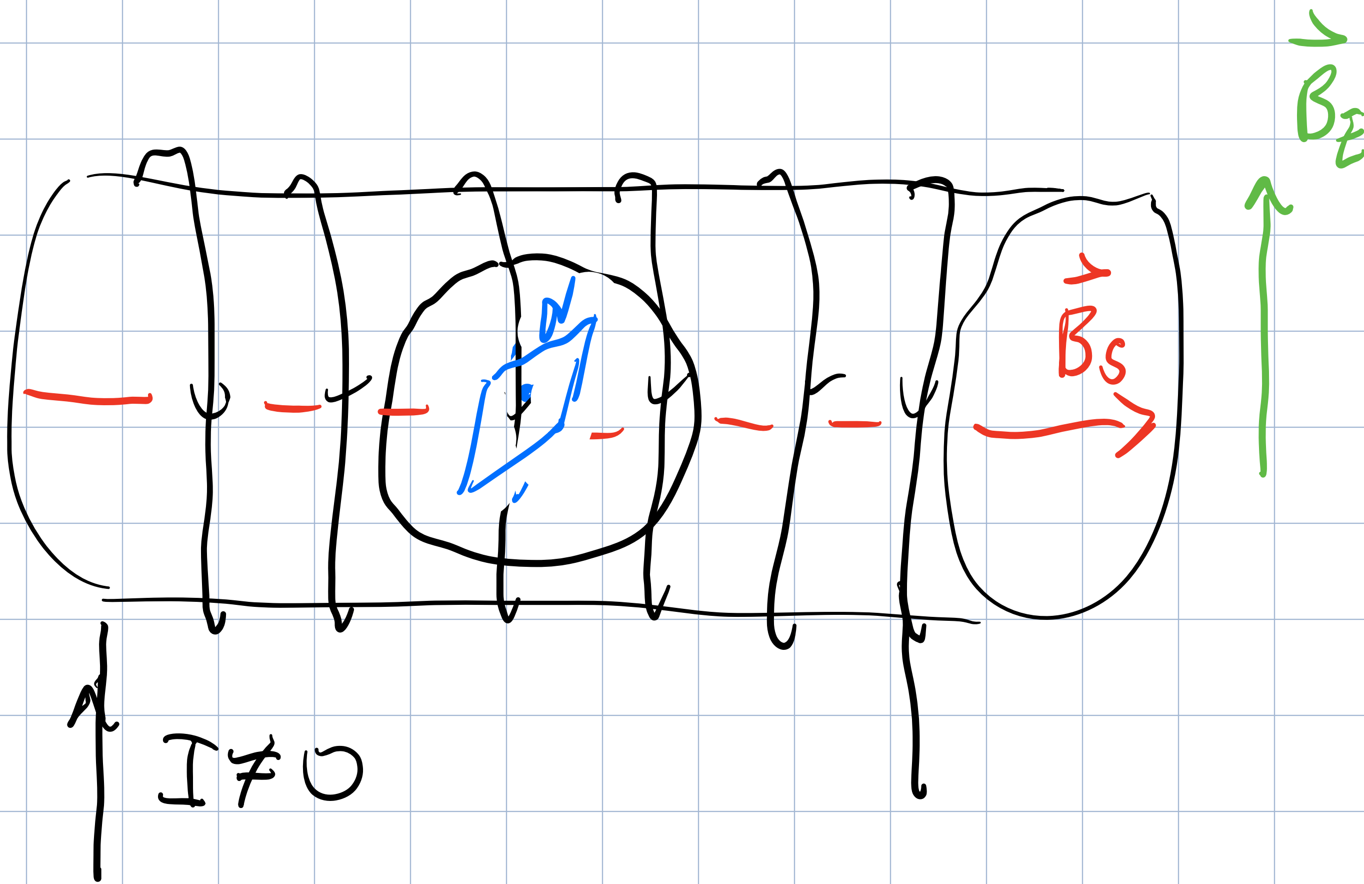
$$|\vec{B}| = B = \mu_0 \frac{N}{L} I$$

N : no. of loops.
L : length of solenoid.

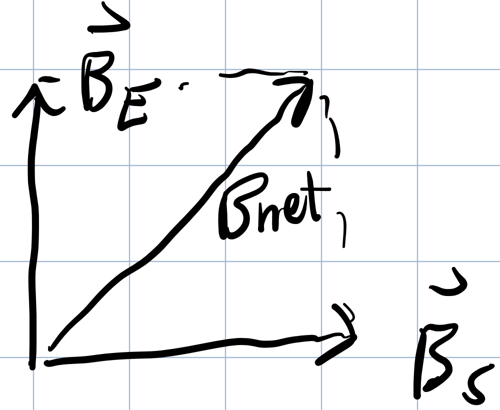
Lab #7 - Use a solenoid to make a uniform magnetic field $B_S = \mu_0 \frac{N}{L} I$

- Place a compass in the centre. Align appratus s.t. compass pts North & is $\perp$ to solenoid axis.





Now net magnetic field @ compass is



Compass rotates to align w/ $\vec{B}_{net}$.
Use rotation to meas. $\vec{B}_E$.