

disadvantage 2:

For a single loop, this model is not very accurate.

Set current to fixed value - in calculating m .

Rewriting in terms of (x, y) :
outside:

$$B_x = \frac{m}{(x^2 + y^2)^{1.5}} \left(\frac{3 \cdot x \cdot x}{x^2 + y^2} - 1 \right)$$

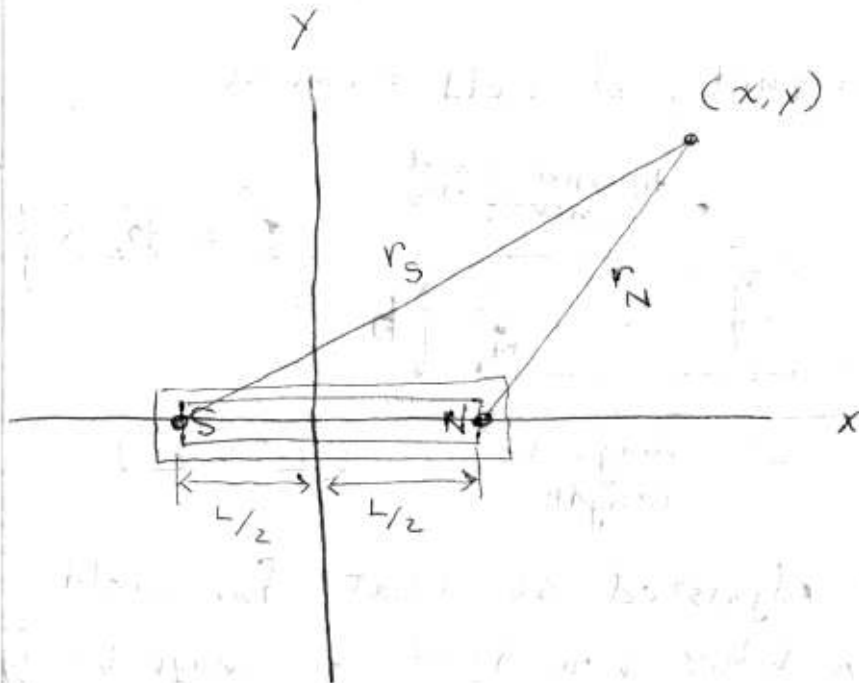
$$B_y = \frac{m}{(x^2 + y^2)^{1.5}} \left(\frac{3 \cdot x \cdot y}{x^2 + y^2} \right)$$

Rewrite m in terms of magnet strength: (my contribution)

Inside the magnet, $B_x = \text{magnet strength}$.

$$\text{So, } m = \frac{(\text{magnet strength}) * R^3}{2}$$

(Dipole) B-field of a bar magnet

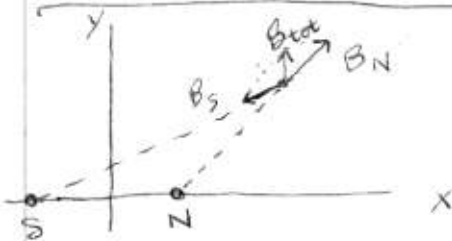


$$r_N = \sqrt{(x - L/2)^2 + y^2}, \quad r_S = \sqrt{(x + L/2)^2 + y^2}$$

$$\vec{B}_{\text{total}} = \vec{B}_S + \vec{B}_N = -\frac{C}{r_S^3} \left[(x + \frac{L}{2}), y \right] + \frac{C}{r_N^3} \left[(x - \frac{L}{2}), y \right]$$

$$\vec{B}_{\text{total}} = [B_x, B_y] = C \left[-\frac{(x + \frac{L}{2})}{r_S^3} + \frac{(x - \frac{L}{2})}{r_N^3}, y \left(\frac{1}{r_N^3} - \frac{1}{r_S^3} \right) \right]$$

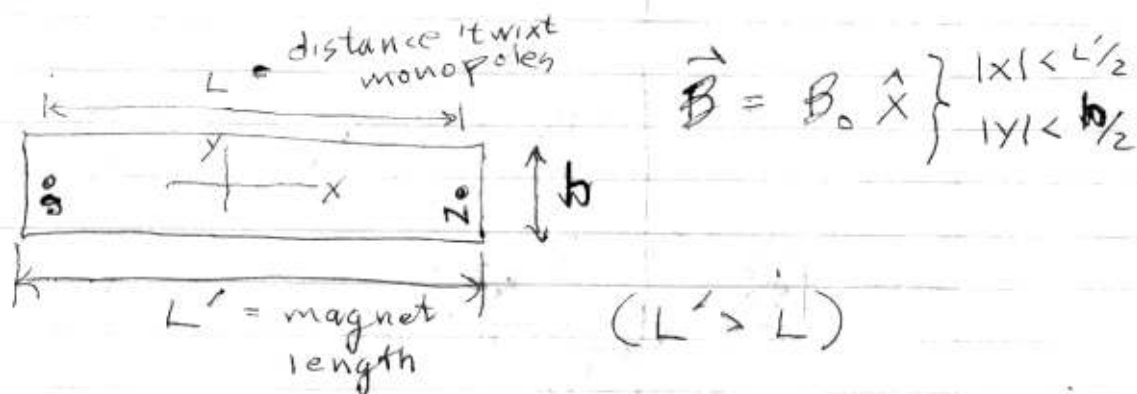
$C = \text{arbitrary (positive) fudge-factor}$



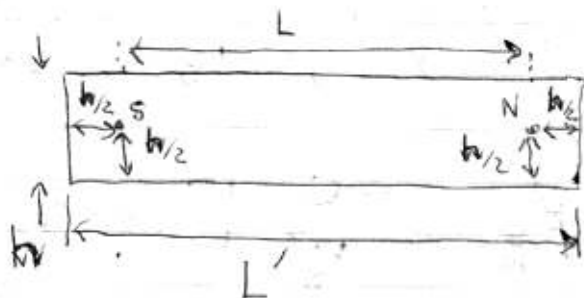
over

Near field vs. far-field B-field

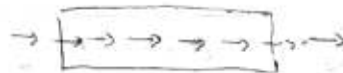
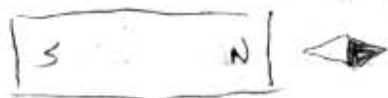
inside magnet, B-field = const



L, L' adjusted so that far-field \approx matches near-field at magnet edges



$$\alpha = B_a \leftarrow \text{fudge}$$

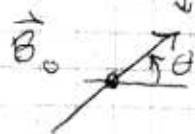


1/04/05

Needle w/ mass m field.



moment of Inertia I
magnet moment μ



$$\omega = \dot{\theta} = \frac{d\theta}{dt}, \quad \alpha = \ddot{\theta} = \frac{d\omega}{dt}$$

torque $\vec{\tau} = \vec{r} \times \vec{F} = \vec{\mu} \times \vec{B} = b \vec{\omega} = I \vec{\alpha}$

$\vec{\mu}$ aligns w \vec{B} (friction)

$$\vec{\mu} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \mu_x & \mu_y & 0 \\ B_x & B_y & 0 \end{vmatrix} = \hat{k} (\mu_x B_y - \mu_y B_x)$$

$$(\vec{\mu} \times \vec{B})_z - b \omega = I \dot{\omega} \quad (\text{sign?})$$

$$\alpha = \frac{(\mu_x B_y - \mu_y B_x) - b \cdot \omega}{I}$$

$\mu_x = \mu \cos \theta$
 $\mu_y = \mu \sin \theta$

$$\textcircled{2} \omega_{n+1} = \omega_n + \alpha_n \Delta t$$

$$\textcircled{1} \theta_{n+1} = \theta_n + \omega_n \Delta t + \frac{1}{2} \alpha_n \Delta t^2$$

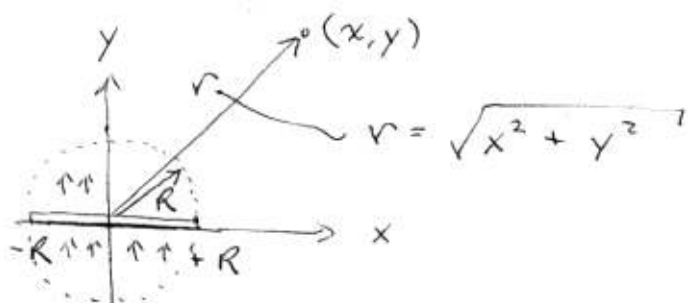
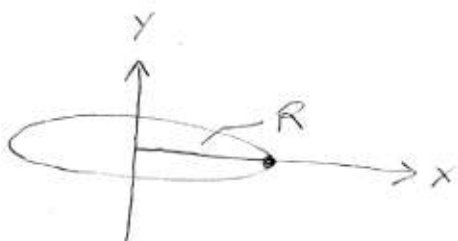
$$\textcircled{3} \alpha_{n+1} = \alpha[\omega_{n+1}, \theta_{n+1}]$$

loop

Adjustable variables

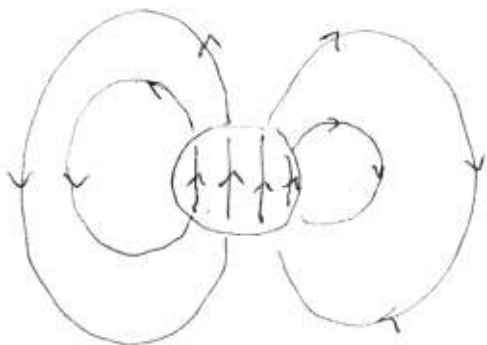
$$\frac{I}{\mu}, \mu, b, \Delta t \Rightarrow \alpha = A (\cos \theta B_y - \sin \theta B_x) - B \omega$$

$$A = \frac{\mu}{I}, \quad \frac{b}{I} = B$$

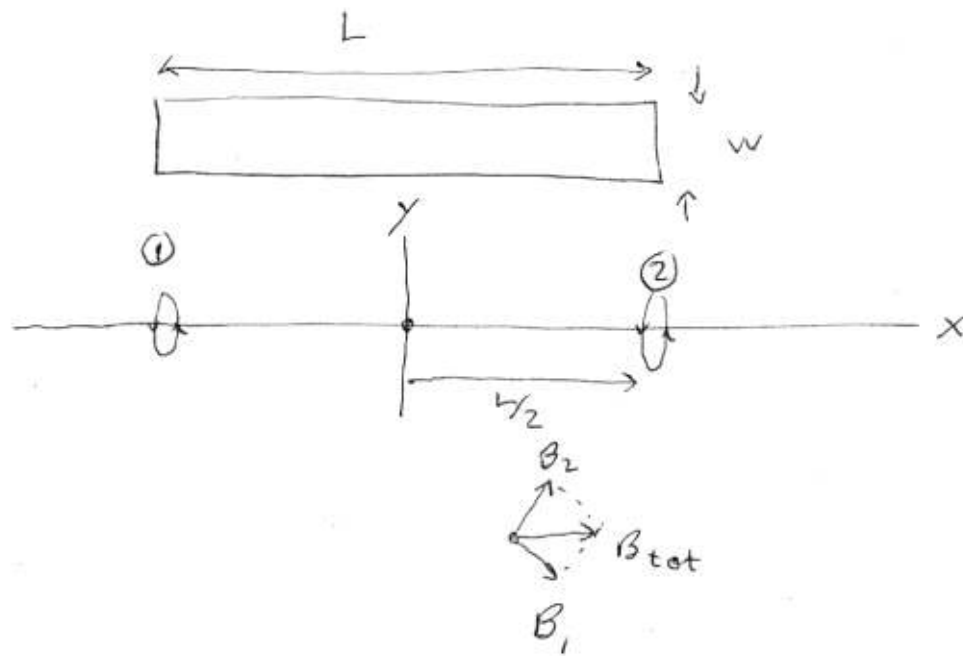


$$\vec{B} = \begin{cases} \vec{B}_{\text{near}} = C \cdot I \hat{y}, & (r < R) \\ \vec{B}_{\text{far}} = \frac{C \cdot I}{2} \left(\frac{R}{r}\right)^2 \left[\underbrace{\frac{3xy}{r^2}}_{\hat{x}}, \underbrace{\left(\frac{3y^2}{r^2} - 1\right)}_{\hat{y}} \right], & (r > R) \end{cases}$$

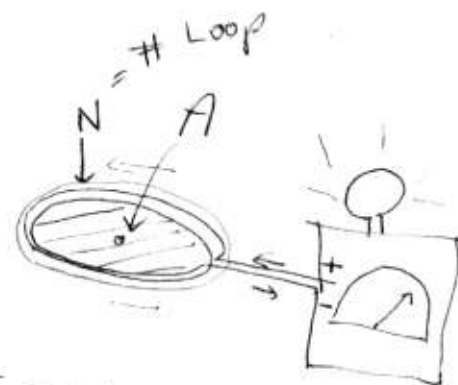
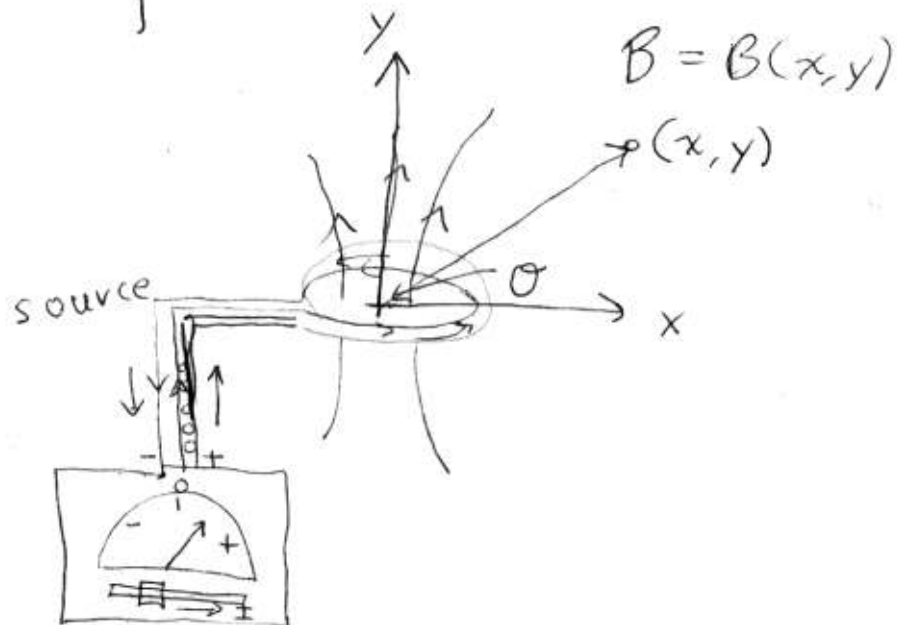
$$B_y = \frac{C \cdot I}{2} \left(\frac{R}{r}\right)^2 \left(\frac{3y^2}{r^2} - 1\right)$$



(2005 -7-)



$$|\mathcal{E}| = \frac{d\Phi}{dt} = N \frac{d}{dt}(BA)$$



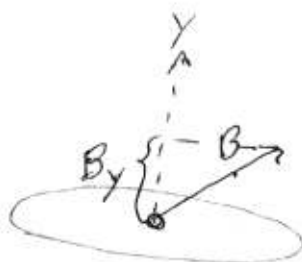
$$\Phi = N \cdot A \cdot B_{avg}$$

$$B_{avg} = B_{center \text{ loop}} \checkmark$$

$$= \frac{B_{center} + B_{edge}}{2}$$

$$\Phi = NAB_y$$

y -component
of B

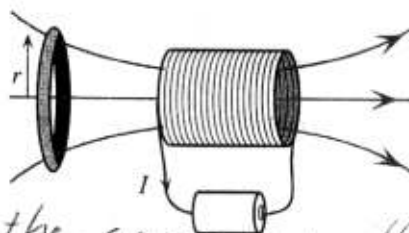


2. A copper wire loop is constructed so that its radius, r , can change. It is held near a solenoid that has a constant current through it.

- a. Suppose that the radius of the loop were increasing. Use Lenz' law to explain why there would be an induced current through the wire. Indicate the direction of that current.

Increasing radius = more flux through loop

Must fight change, therefore the current will flow clockwise up the front the front and back down the back.



- b. Check your answer regarding the direction of the induced current by considering the magnetic force that is exerted on the charge in the wire of the loop.

It is correct because the magnetic moment points to the left.

- c. Find:

- the direction of the magnetic moment of the loop and

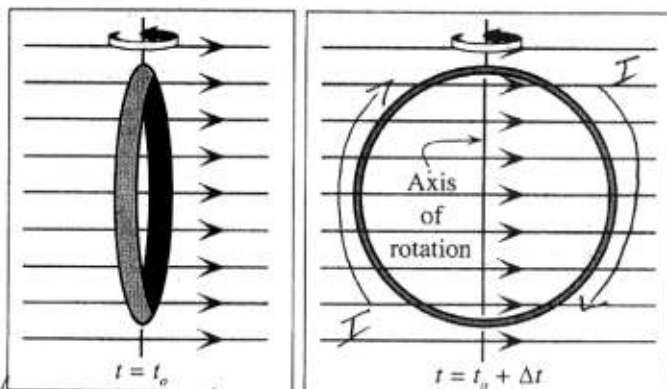
$\leftarrow \odot \mu$ Points to the left.

- the direction of the force exerted on the loop by the solenoid.

$\leftarrow \bigcirc$ The force points to the left
why?

3. A copper wire loop is initially at rest in a uniform magnetic field. Between times $t = t_0$ and $t = t_0 + \Delta t$ the loop is rotated about a vertical axis as shown.

Will current flow through the wire of the loop during this time interval? If so, indicate the direction of the induced current and explain your reasoning. If not, explain why not.



Current flows during the interval since the flux through the loop gets reduced. We must fight the change, therefore the induced current will flow clockwise as shown in the diagram.