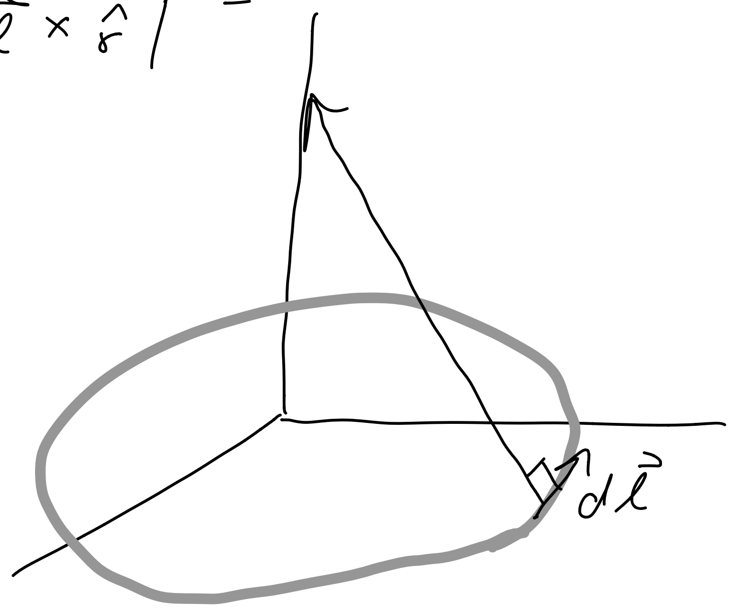
$$dB_z = |d\vec{B}| \frac{R}{\sqrt{R^2+z^2}}$$

$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{d\vec{l} \times \hat{r}}{r^2}$$

$$|d\vec{l} \times \hat{r}| = |d\vec{l}|\,|\hat{r}| \sin(\delta)$$

$$\delta = \frac{\pi}{2}$$

$$|d\vec{l} \times \hat{r}| = |d\vec{l}|$$



$$d\vec{B} = \frac{\mu_0 I}{4\pi} \frac{|d\vec{l}|}{r^2} \hat{z}$$

$$|d\vec{\ell}| = R\,d\varphi \qquad \left(\theta = \frac{S}{R}\right)$$

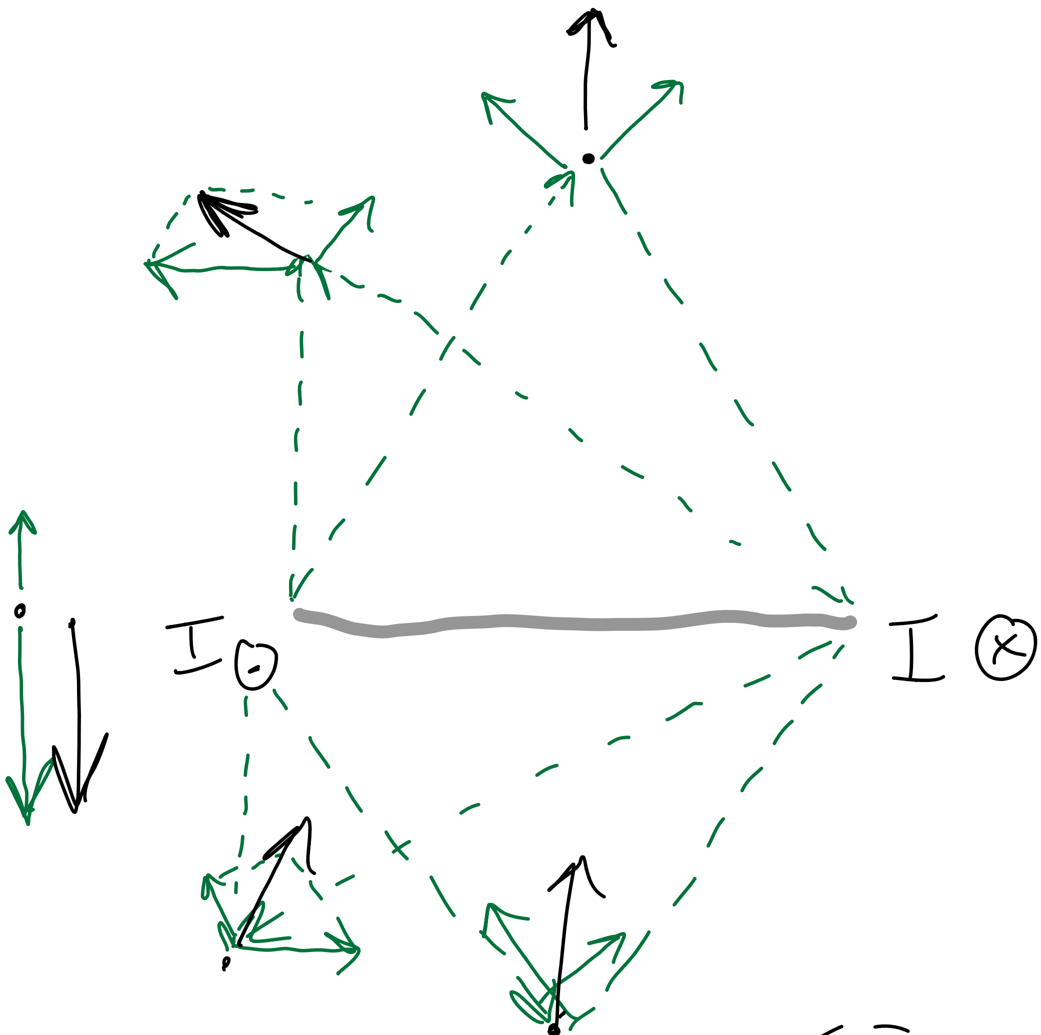
$$|d\vec{B}| = \frac{\mu_0}{4\pi}\,\frac{I\,R\,d\varphi}{R^2+z^2}$$

$$dB_z = |d\vec{B}|\frac{R}{\sqrt{R^2+z^2}}$$

$$dB_z = \frac{\mu_0}{4\pi}\,\frac{I\,R^2\,d\varphi}{(R^2+z^2)^{3/2}}$$

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{IR^2}{(R^2+z^2)^{3/2}}\int_0^{2\pi} d\varphi \quad \hat{z}$$

$$\vec{B} = \frac{\mu_0}{4\pi}\,\frac{2\pi R^2 I}{(R^2+z^2)^{3/2}}\,\hat{z}$$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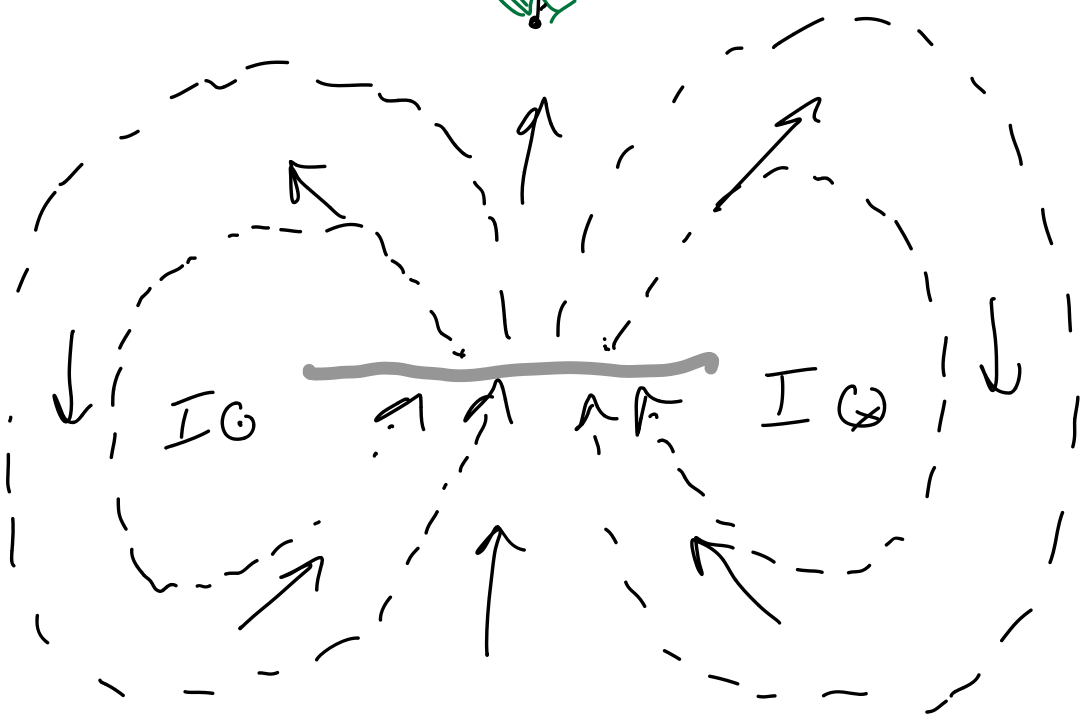
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$$\vec{B} = \frac{\mu_0}{4\pi} \frac{2\pi R^2 I}{(R^2+z^2)^{3/2}} \hat{z}$$

if $z >> R$

$$(R^2+z^2)^{3/2} = z^3\left(\underbrace{\left(\frac{R}{z}\right)^2}_{\approx 0}+1\right)^{3/2}$$

$$\approx z^3$$

$$\left|\vec{B}\right| \approx \frac{\mu_0}{4\pi} \frac{2\pi R^2 I}{z^3}$$

$$\pi R^2 = A$$

$$|\vec{B}| = \frac{\mu_0}{4\pi} \frac{2AI}{r^3}$$

Look Familiar?

$$|\vec{E}| = \frac{1}{4\pi\epsilon_0} \frac{2qs}{r^3}$$

Magnetic dipole

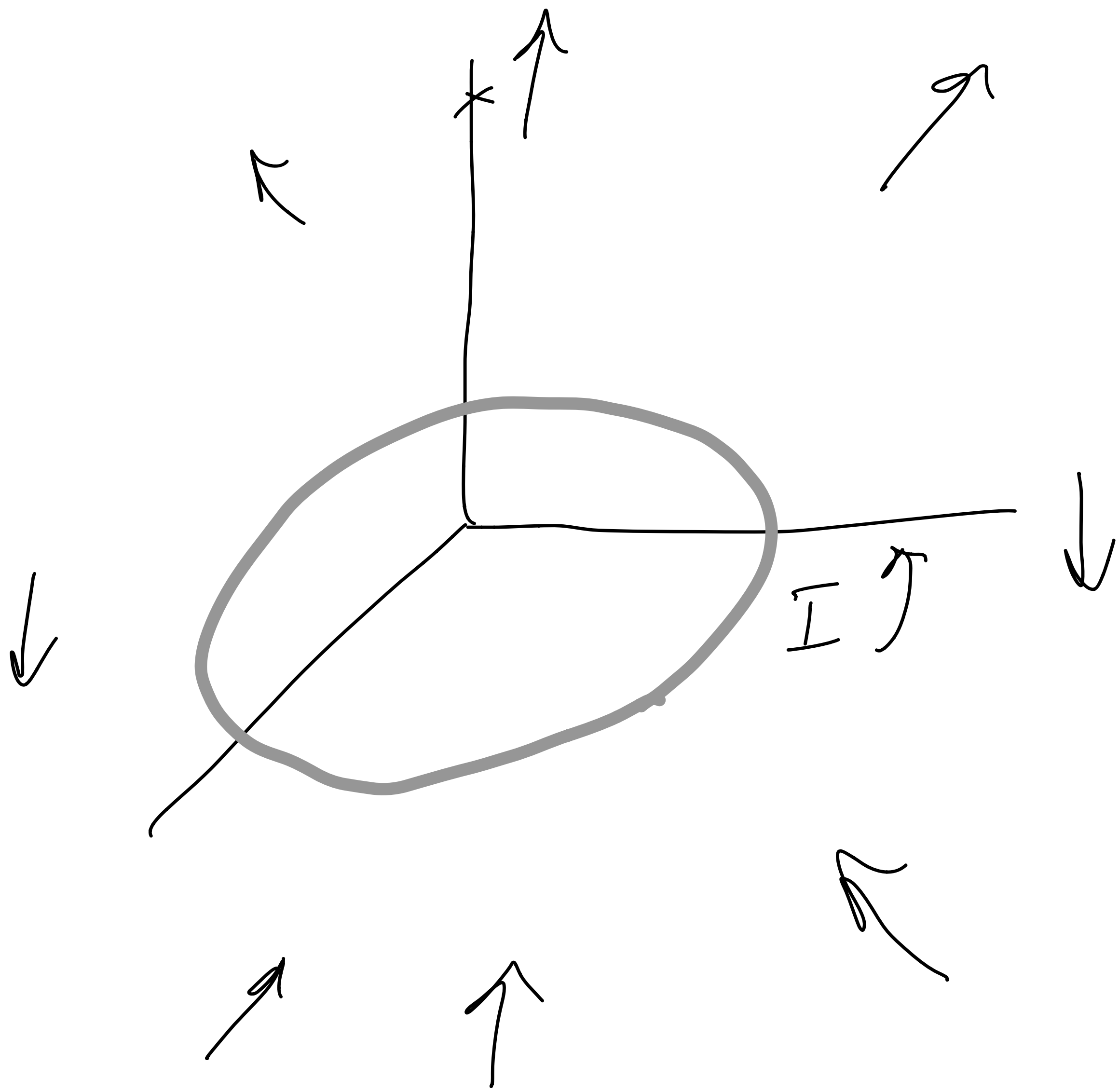
$$\frac{1}{4\pi\epsilon_0} \longrightarrow \frac{\mu_0}{4\pi}$$

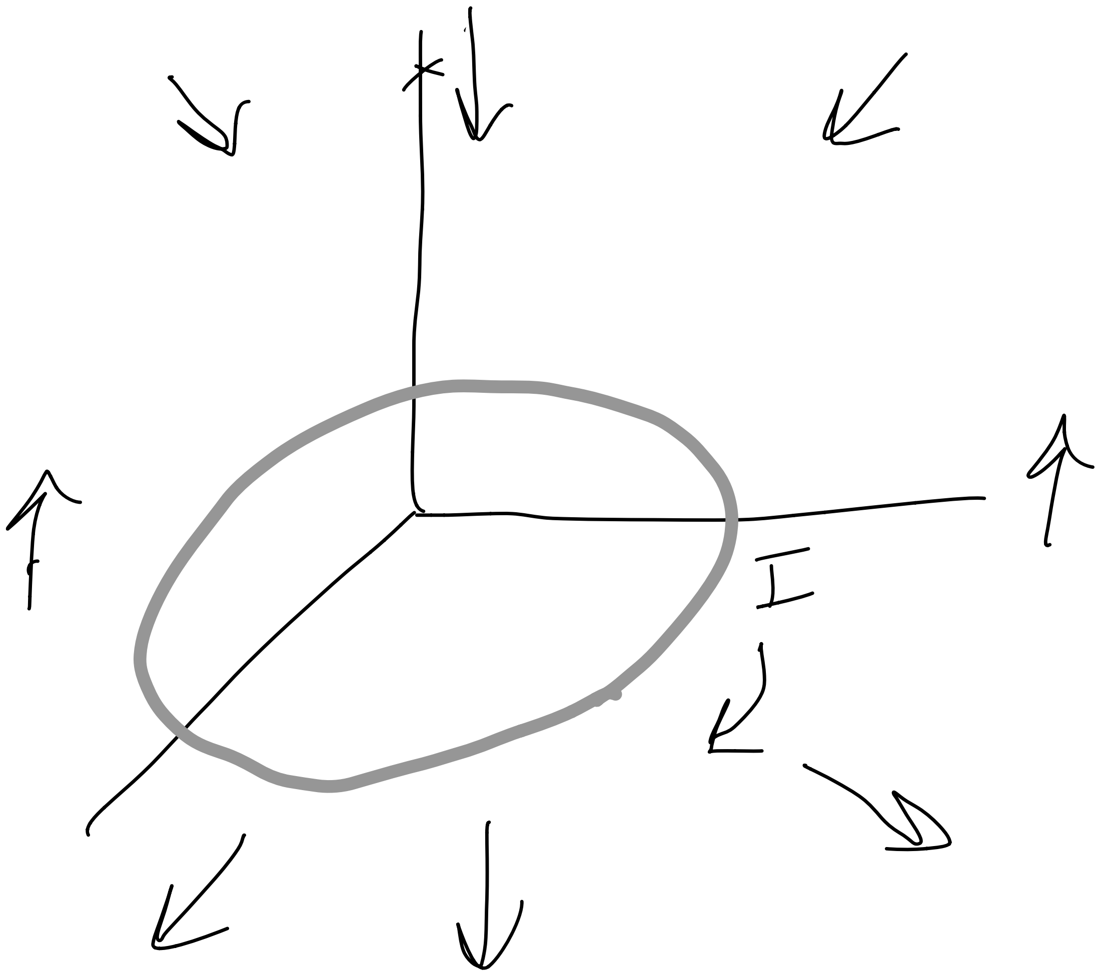
$$qs = p \longrightarrow IA = \mu$$

Dipole, on axis:

$$|\vec{B}| = \frac{\mu_0}{4\pi} \frac{2\mu}{r^3}$$

Direction of dipole field?
- Depends on current

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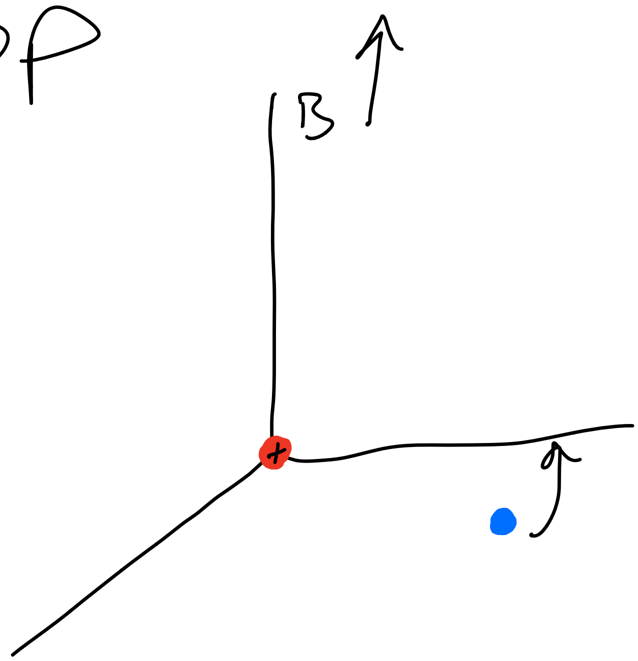
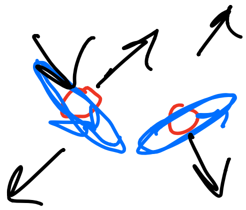
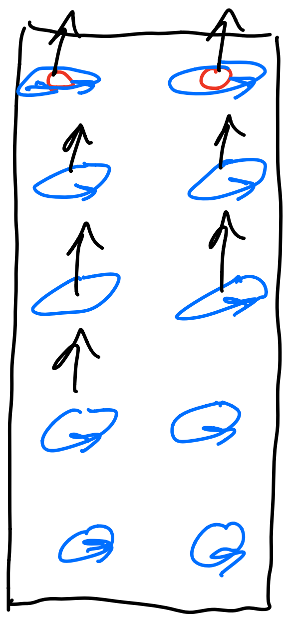
Magnetic Materials

An atom is a tiny current loop

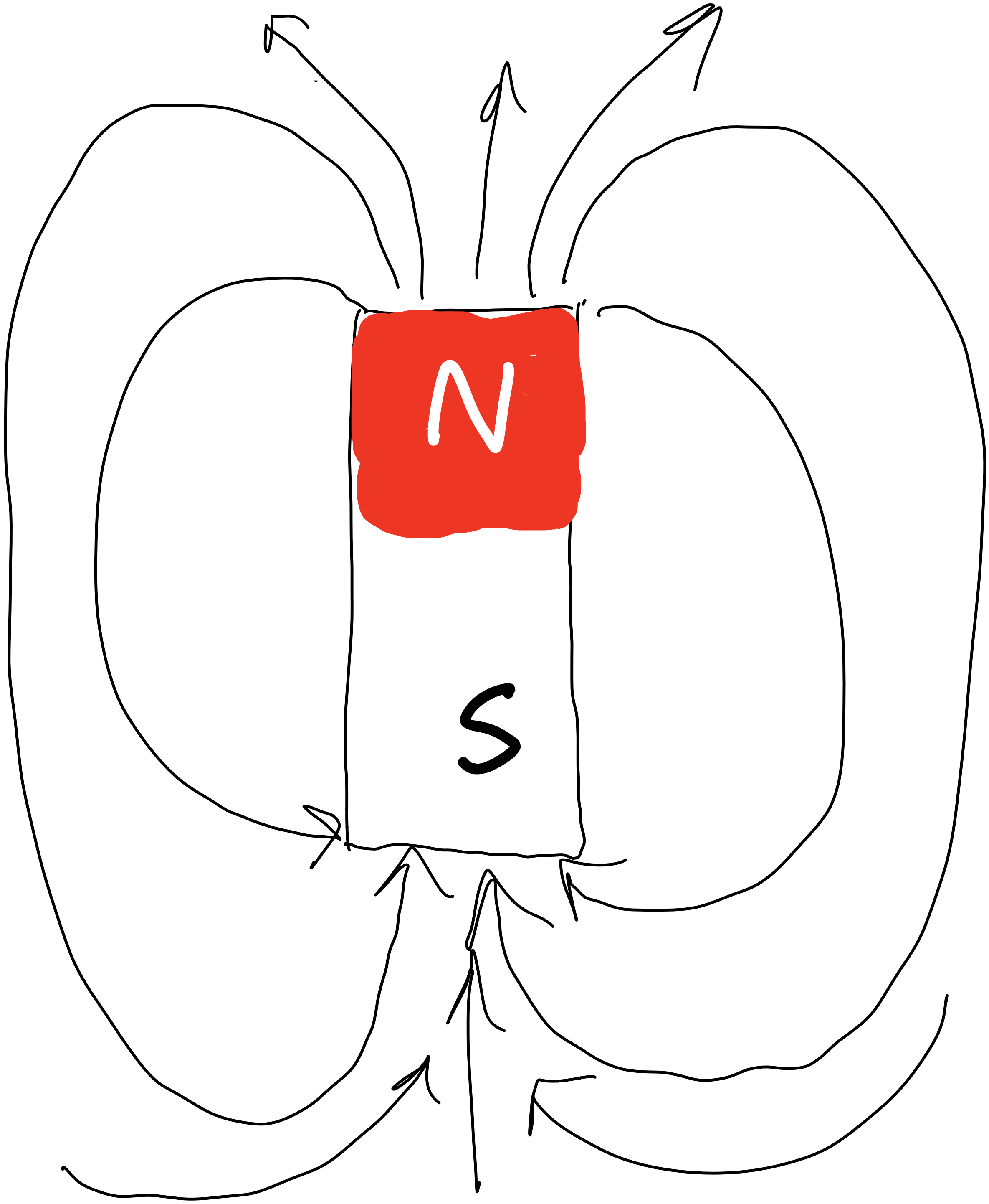




In most materials $\vec{B}$ cancels



Net $\vec{B}$



Field lines: Toward S
Away N


Geo
North
pole


Geo
North
pole