

FISICA 1 (PALEONTOLOGÍA)

2DO CUATRIMESTRE 2020

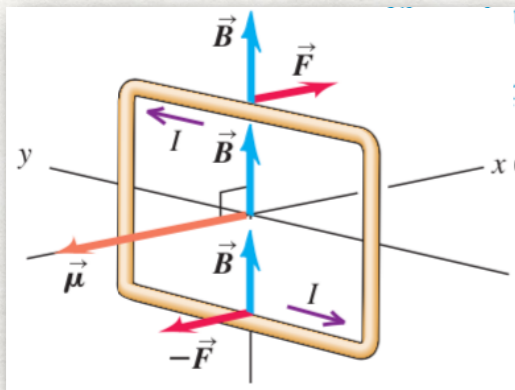
CLASE 20

RODOLFO SASSOT

CLASE 20: Magnetismo

Temas: Dipolo magnético, solenoides, Ley de Biot y Savart

dipolo magnético: (continuación Clase 19)

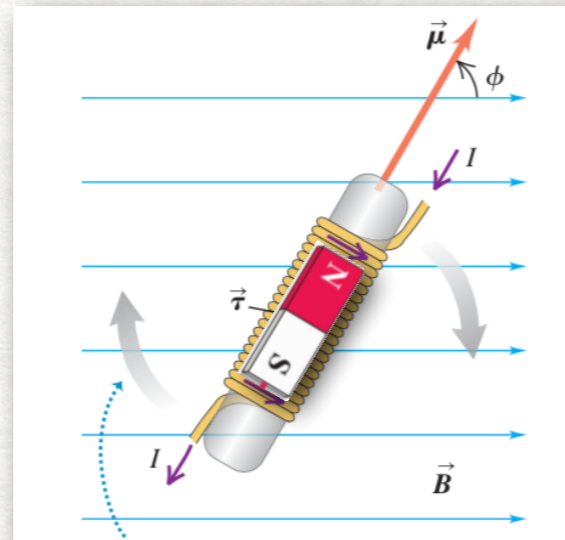
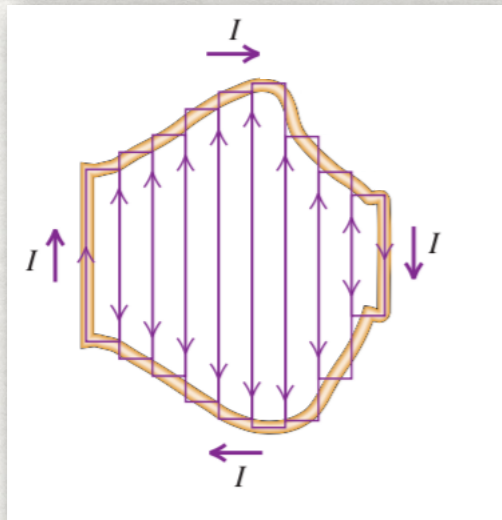
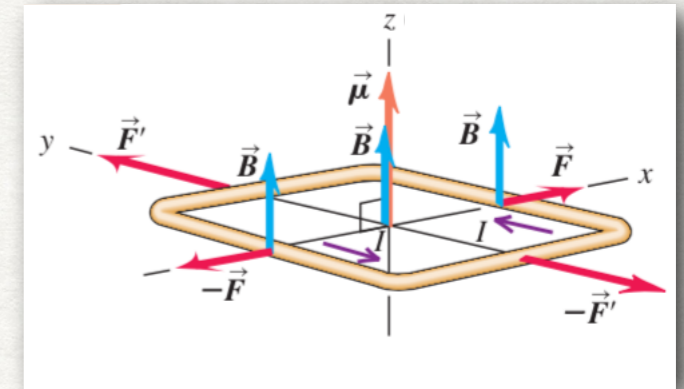


$$\vec{\tau} = \vec{\mu} \times \mathbf{B}$$

$$\vec{\mu} = A I \hat{n}$$



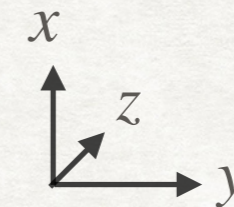
"dipolo magnético"



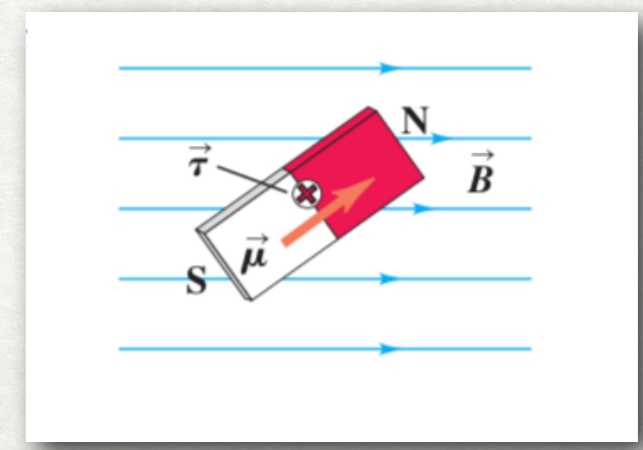
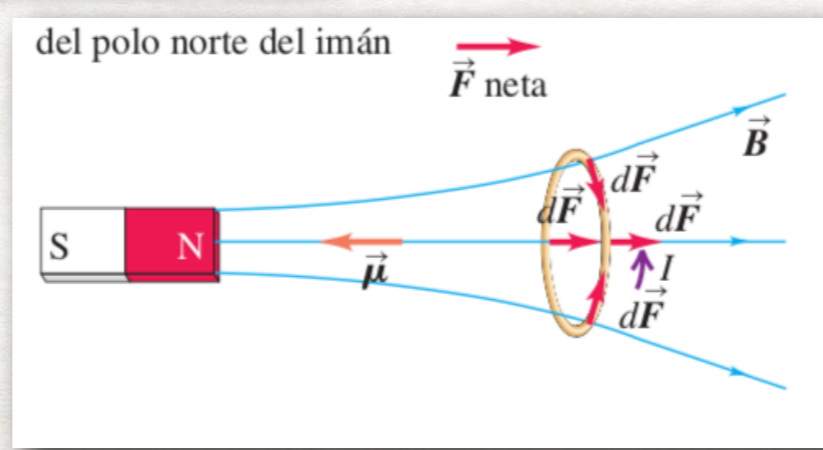
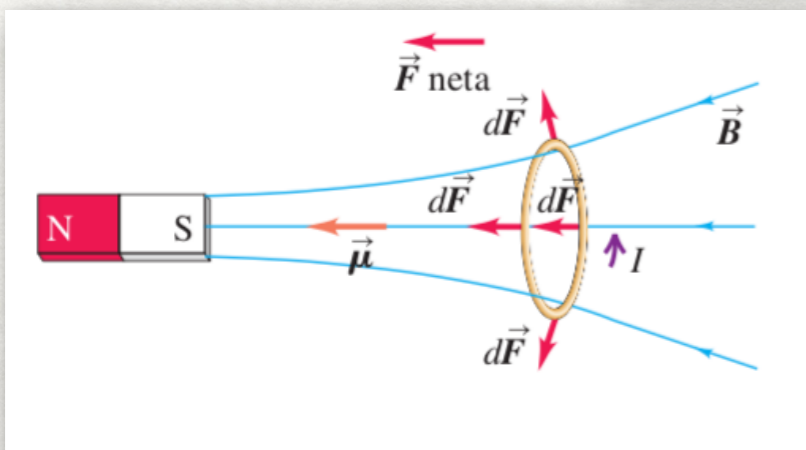
"solenoid"

$$\mu = n A I$$

$$\vec{\tau} = \vec{\mu} \times \mathbf{B}$$

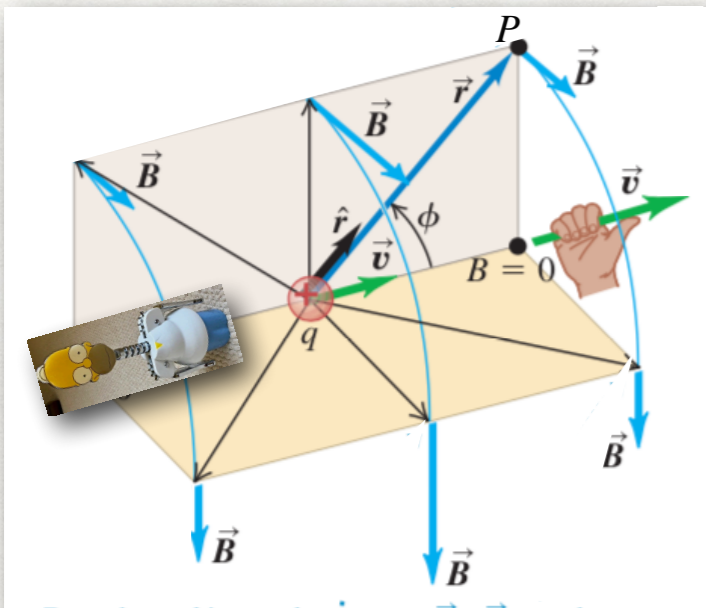


un imán permanente ~ dipolo magnético
magnetización ~ orden
corriente debe generar **B**



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campo magnético de una carga en movimiento:



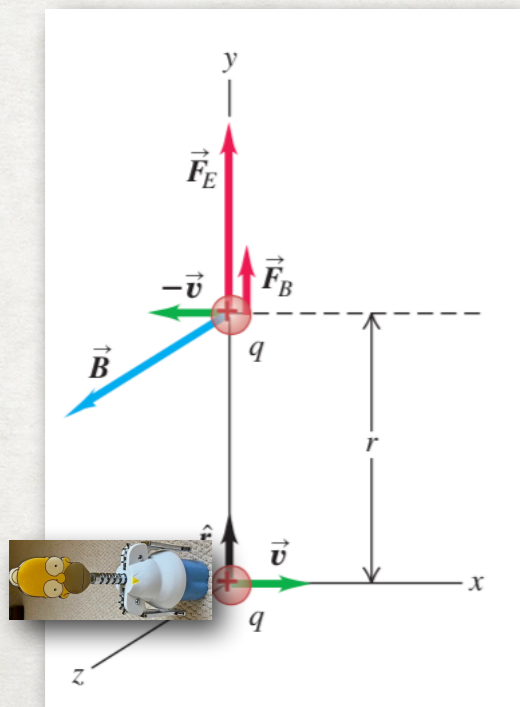
$$B = \frac{\mu_0}{4\pi} \frac{|q| v \sin\phi}{r^2}$$

$$\mu_0 = 4\pi \cdot 10^{-7} \frac{T \cdot m}{A}$$

$$\mu_0 = \frac{1}{\epsilon_0 c^2}$$

$$\mathbf{B} = \frac{\mu_0}{4\pi} \frac{q \mathbf{v} \times \hat{\mathbf{r}}}{r^2}$$

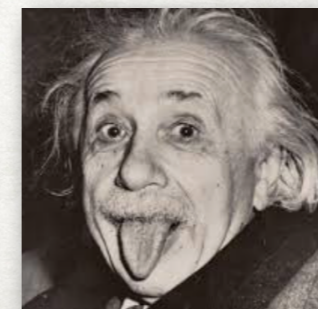
ejemplo: dos protones en movimiento



$$\mathbf{F}_E = \frac{1}{4\pi \epsilon_0} \frac{q^2}{r^2} \hat{\mathbf{j}} \quad \mathbf{B} = \frac{\mu_0}{4\pi} \frac{q v \hat{\mathbf{i}} \times \hat{\mathbf{j}}}{r^2} = \frac{\mu_0}{4\pi} \frac{q v}{r^2} \hat{\mathbf{k}}$$

$$\mathbf{F}_B = q \mathbf{v} \times \mathbf{B} = q (-v \hat{\mathbf{i}}) \times \left(\frac{\mu_0}{4\pi} \frac{q v}{r^2} \hat{\mathbf{k}} \right) = \frac{\mu_0}{4\pi} \frac{q^2 v^2}{r^2} \hat{\mathbf{j}}$$

$$\frac{F_B}{F_E} = \frac{\frac{\mu_0}{4\pi} \frac{q^2 v^2}{r^2}}{\frac{1}{4\pi \epsilon_0} \frac{q^2}{r^2}} = \mu_0 \epsilon_0 v^2 = \frac{v^2}{c^2}$$



$$v_{LHC} = 0.9999999991 c$$

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campo magnético de un elemento de corriente:

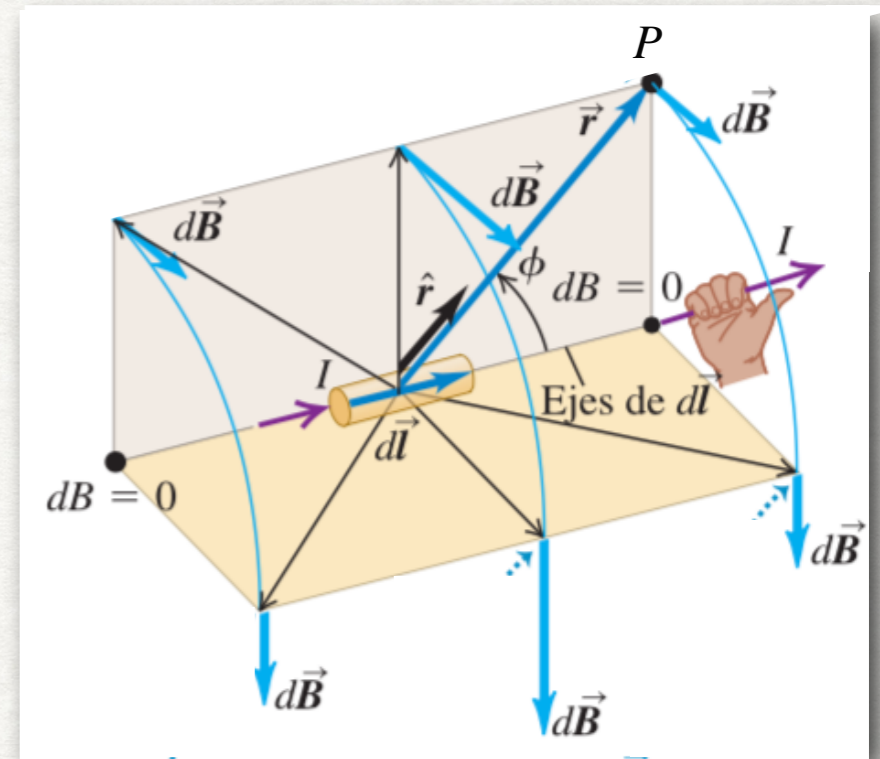
$$\mathbf{B} = \frac{\mu_0}{4\pi} \frac{q \mathbf{v} \times \hat{\mathbf{r}}}{r^2}$$

$$dq = n q A dl \quad (\text{Clase 17})$$

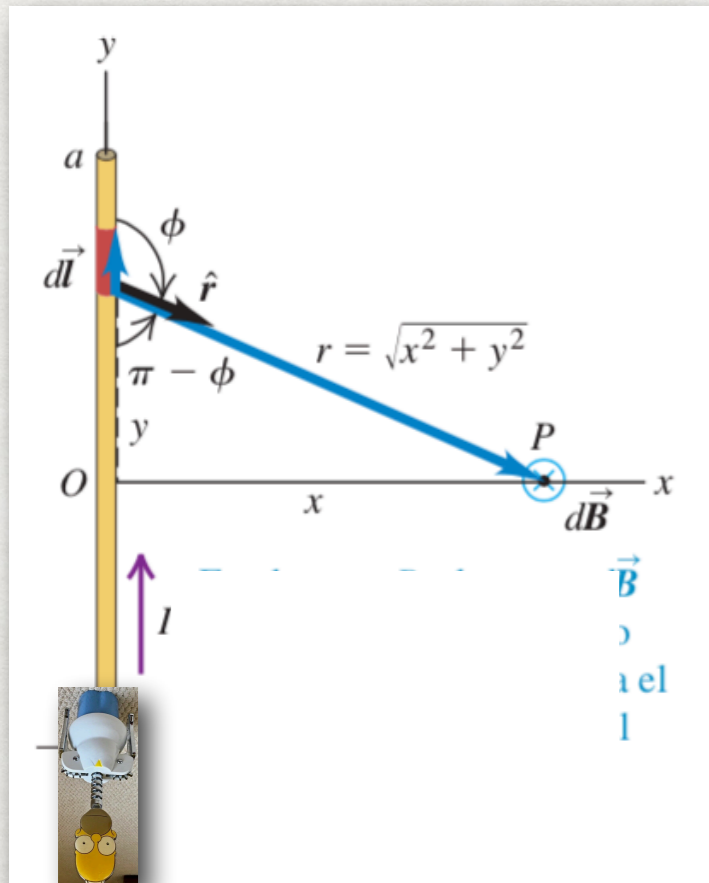
$$I = n q A v_d \quad dq = \frac{I}{v_d} dl$$

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

Ley de Biot (1774 –1862) y Savart (1791-1841)



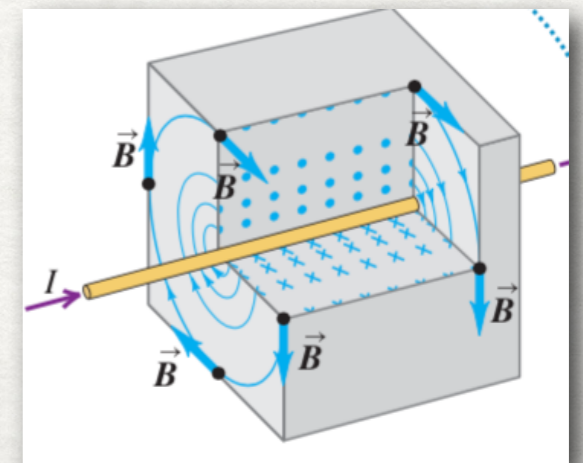
ejemplo: conductor recto



$$dB = \frac{\mu_0}{4\pi} \frac{I dy}{r^2} \text{sen}\phi \quad r^2 = x^2 + y^2 \quad \text{sen}\phi = \frac{x}{(x^2 + y^2)^{1/2}}$$

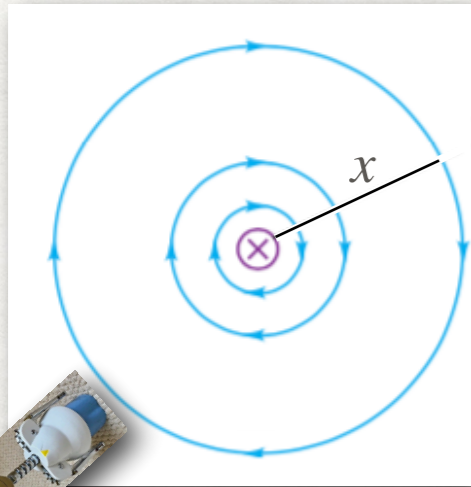
$$dB = \frac{\mu_0 I}{4\pi} \frac{x dy}{(x^2 + y^2)^{3/2}} \quad B = \frac{\mu_0 I}{4\pi} \int_{-a}^a \frac{x dy}{(x^2 + y^2)^{3/2}} = \frac{\mu_0 I}{4\pi} \frac{2a}{x(x^2 + a^2)^{1/2}}$$

$$a \gg x \quad \sqrt{x^2 + a^2} \rightarrow a \quad B = \frac{\mu_0 I}{2\pi x}$$

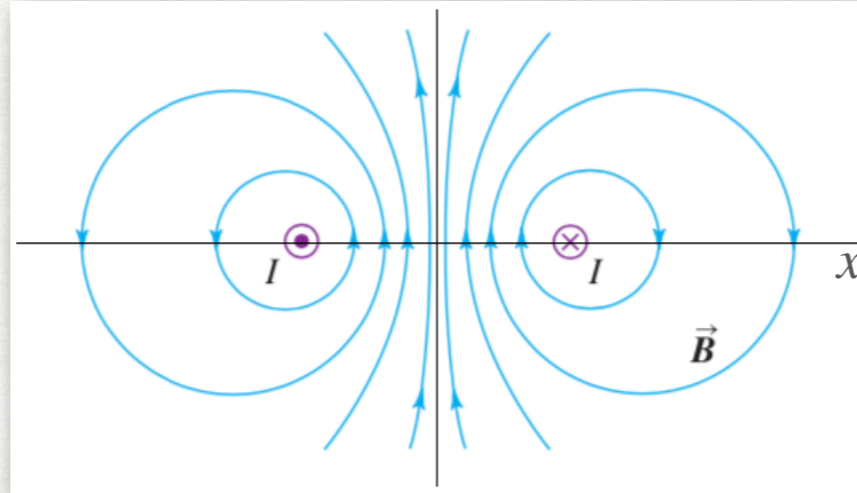


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campo magnético de dos corrientes paralelas:



$$B = \frac{\mu_0 I}{2\pi x}$$



$$|B_1| = \frac{\mu_0 I}{2\pi |x + d|} \quad |B_2| = \frac{\mu_0 I}{2\pi |x - d|}$$

$$x > d \quad \mathbf{B}_1 = \frac{\mu_0 I}{2\pi (x + d)} \hat{\mathbf{j}}$$

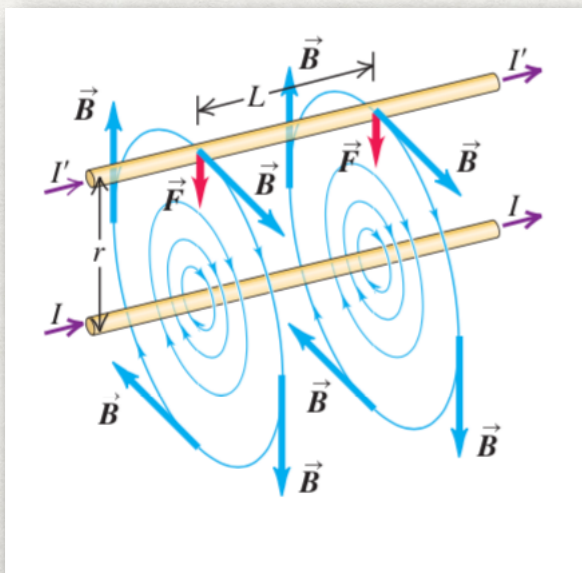
$$\mathbf{B}_2 = -\frac{\mu_0 I}{2\pi (x - d)} \hat{\mathbf{j}}$$

$$\mathbf{B} = \mathbf{B}_1 + \mathbf{B}_2 = \left(\frac{\mu_0 I}{2\pi (x + d)} - \frac{\mu_0 I}{2\pi (x - d)} \right) \hat{\mathbf{j}}$$

$$= -\frac{\mu_0 I d}{\pi (x^2 - d^2)} \hat{\mathbf{j}}$$

$$x \gg d \quad \mathbf{B} \simeq -\frac{\mu_0 I d}{\pi x^2} \hat{\mathbf{j}}$$

fuerza entre dos corrientes paralelas:



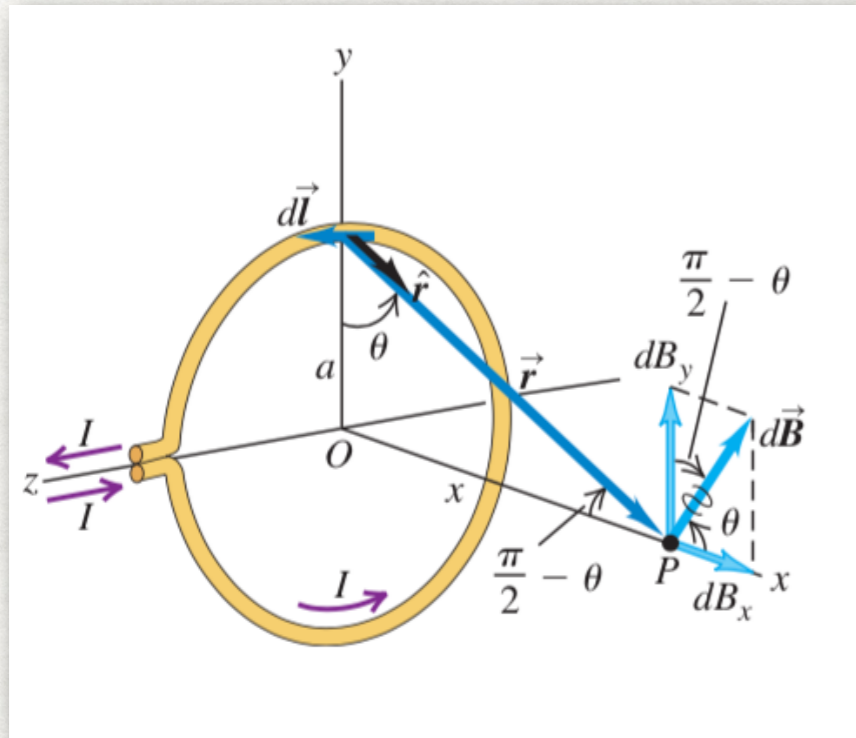
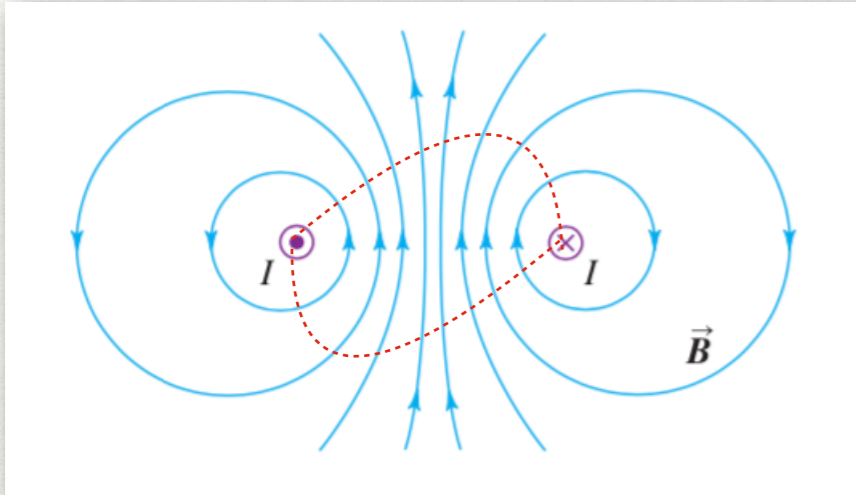
$$\mathbf{F} = I' \mathbf{L} \times \mathbf{B} \quad (\text{Clase 17})$$

$$F = I' L B = I' L \frac{\mu_0 I}{2\pi r} \quad \frac{F}{L} = I' I \frac{\mu_0}{2\pi r}$$

CLASE 20: Magnetismo

campo magnético de una espira:

una espira se comporta como un imán permanente
 ~ debería generar un campo \mathbf{B} similar



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

$$dB = \frac{\mu_0}{4\pi} \frac{I dl}{r^2} = \frac{\mu_0 I}{4\pi} \frac{dl}{a^2 + x^2}$$

$$dB_x = dB \cos\theta = \frac{\mu_0 I}{4\pi} \frac{dl}{a^2 + x^2} \frac{a}{(a^2 + x^2)^{1/2}}$$

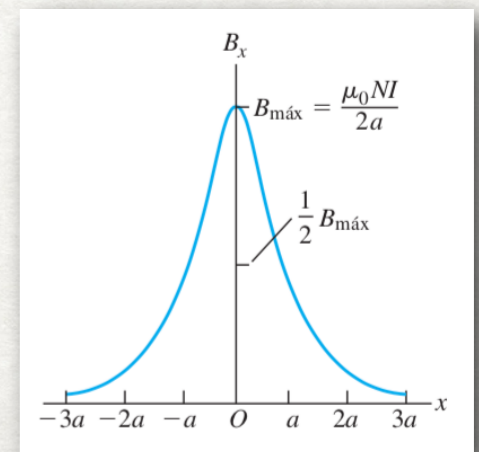
$$dB_y = dB \sin\theta = \frac{\mu_0 I}{4\pi} \frac{dl}{a^2 + x^2} \frac{x}{(a^2 + x^2)^{1/2}}$$

$$B_x = \int dB_x = \int \frac{\mu_0 I}{4\pi} \frac{a dl}{(a^2 + x^2)^{3/2}} = \frac{\mu_0 I}{4\pi} \frac{a}{(a^2 + x^2)^{3/2}} \int dl$$

$$B_x = \frac{\mu_0 I}{4\pi} \frac{a}{(a^2 + x^2)^{3/2}} 2\pi a$$

$$B_x = \frac{\mu_0 I}{2} \frac{a^2}{(a^2 + x^2)^{3/2}} \sim \frac{1}{x^3}$$

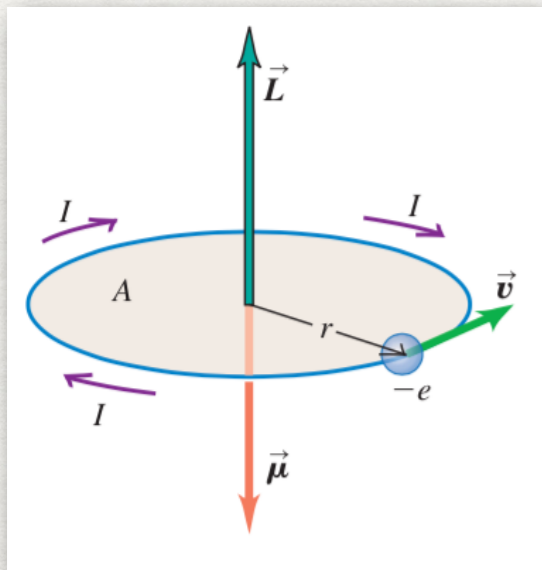
"sobre el eje"



CLASE 20: Magnetismo

materiales magnéticos: toda la materia está compuesta por átomos, con electrones en movimiento
 ~"podemos pensarlos" como micro-espiras que generan **B**

un material "magnetizado" es aquel donde algo orientó esas micro-espiras



$$\vec{\mu} = A I = \frac{e v r}{2} = \frac{e L}{2m}$$

$$L = 0, \hbar, 2\hbar, 3\hbar, \dots \quad \hbar = 1.05 \cdot 10^{-34} \text{ J/s}$$

$$A = \pi r^2$$

$$I = \frac{e}{T} = \frac{e v}{2 \pi r}$$

$$\vec{\mu}_B = \frac{e \hbar}{2m}$$

magnetón de Bohr

$$\mathbf{L} = \mathbf{r} \times m\mathbf{v}$$

$$\mathbf{J} = \mathbf{L} + \mathbf{S} \quad \mathbf{S} \text{ "espín"}$$

para la mayoría de los átomos $\mu \sim 0$, para algunos $\mu = \mu_B$. En presencia de un \mathbf{B}_0 , $\vec{\tau} = \vec{\mu} \times \mathbf{B}_0$

$$\vec{\mu}_{total} = \sum \vec{\mu} \quad \mathbf{M} = \frac{\vec{\mu}_{total}}{V} \quad \text{magnetización}$$

$\mathbf{B} = \mathbf{B}_0 + \mu_0 \mathbf{M}$ material paramagnético: el campo es mas intenso que en el vacío $\mu_0 \rightarrow \mu = K_m \mu_0$

material diamagnético: el campo es menos intenso que en el vacío

$$K_m \sim 1 - 65 \times 10^{-5}$$

material ferromagnético: $K_m \sim 1000 - 100000$

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resonancia magnética:

