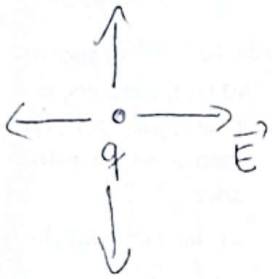
Cap 28: Campos magnéticos

Lei de Ohm 1827 — 1880 Tesla

Grécia antiga — 1820 Oersted e Lei de Biot-Savart — Efeito Hall (1879) descoberta do elétron (Thomson 1897) — 1864 Maxwell

1300ac a 146ac
640ac 550ac Tales de Mileto

Vimos:

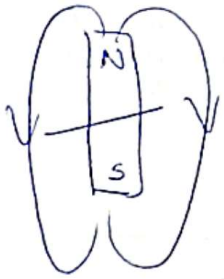


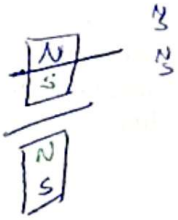
carga elétrica

$\Rightarrow \oint \vec{B} \cdot d\vec{A} = 0$

$\vec{B}$?

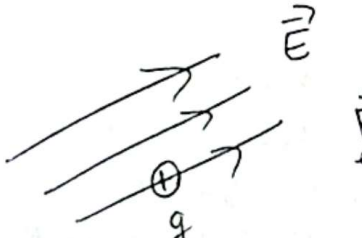
$q_{magnética}$





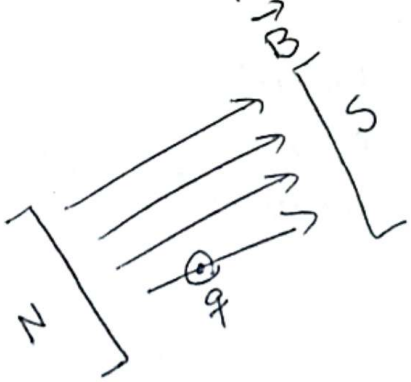
* não existe monopolo magnético (carga magnética)

- Campos magnéticos gerados por corrente elétrica (Cap 29)
- Partículas carregadas em um campo magnético:



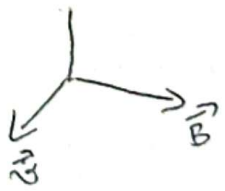
$\vec{F}_e = q\vec{E}_{externo}$

Vimos



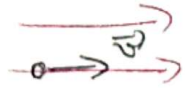
$\vec{F}_B = q\vec{v} \times \vec{B}_{ext}$

$|F_B| = |q||\vec{v}||\vec{B}|\sin\phi$





$\vec{F}_B = q\vec{v} \times \vec{B}$



$\Rightarrow F_B = 0$ (fio)

$\Rightarrow$ Campos cruzados: $[F_B] = N \Rightarrow [B] = \frac{[F]}{[q][\vec{v}]} = \frac{N}{C \cdot m/s} = \frac{N}{A \cdot m} = T$ (Tesla)

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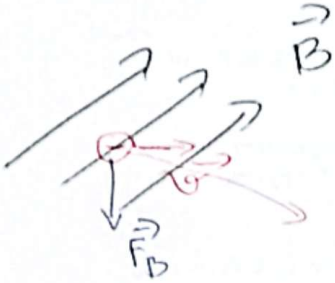
2 Campos cruzados: • A descoberta do elétron 1879 Thomson (não vamos falar)

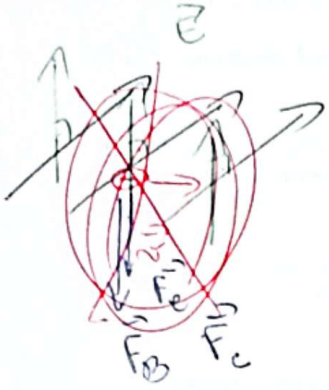
• A velocidade da partícula.

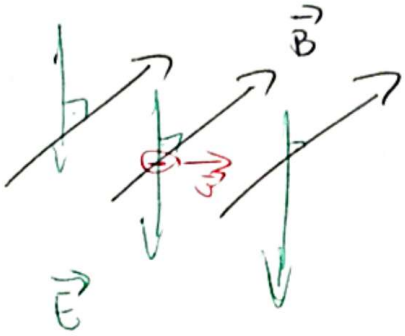


$$\vec{F}_B = q\,\vec{v} \times \vec{B}$$

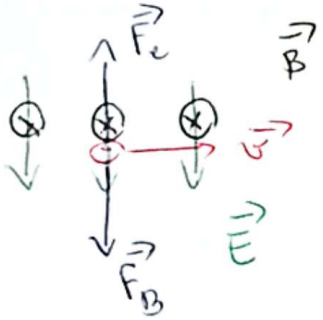
sofre um desvio

Vamos incluir um campo ~~magnético~~ elétrico. para compensar este desvio.





Vista de frente:



$$\vec{F}_e = q\,\vec{E}$$

$$\vec{F}_B = q\,\vec{v} \times \vec{B}$$

$$|\vec{F}_e| = |\vec{F}_B|$$

$$q|E| = q|\vec{v}||B| \sin 90$$

$$|v| = \frac{|\vec{E}|}{|\vec{B}|}$$

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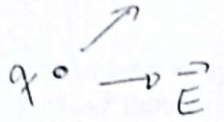
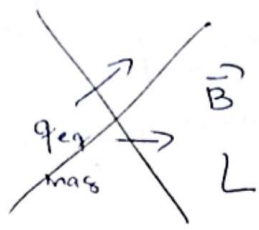
Cap 28: Campos magnéticos

Vimos



$$\vec{E} = \frac{\vec{F}_E}{q}$$



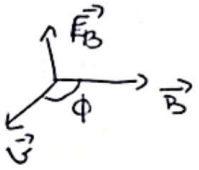
não!

campo magnético

?

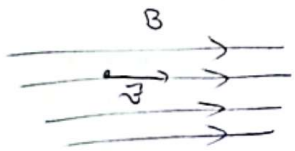
$$\vec{F}_B = q\,\vec{v} \times \vec{B}$$

↳ produto vetorial

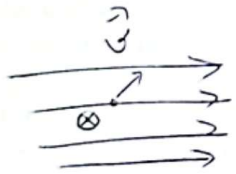


$$|\vec{F}_B| = q|\vec{v}||\vec{B}|\,\text{sen}\,\phi$$

→ A força sobre uma partícula carregada em movimento ~~devido a presença~~ em um campo magnético B



$$\Rightarrow \vec{F}_B = 0$$



$$\vec{F}_B = q\,\vec{v} \times \vec{B}$$

$$[B] = \frac{[F]}{[q][\vec{v}]} = \frac{N}{C.m/s} = \frac{N}{A.m} = T \quad \text{tesla.}$$

1820 Oersted observou campo magnético ~~o~~ nas prox. de um fio quando estava preparando sua aula.

. mas como produzimos os campos?

. carga em movimento (Cap 29)

. Propriedade intrínseca de alguns materiais:

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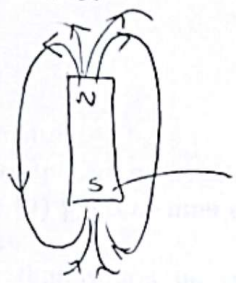
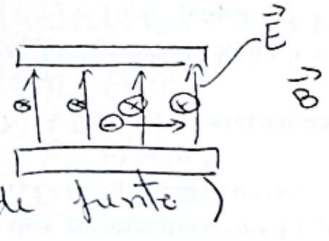
Imãs

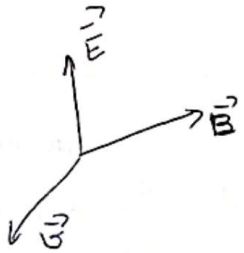


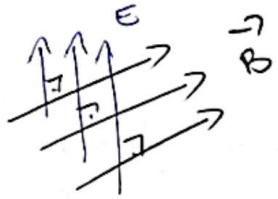
pólo magnético

não existe um monopolo magnético!

- Campos cruzados (A descoberta do elétron Thomson - 1897)





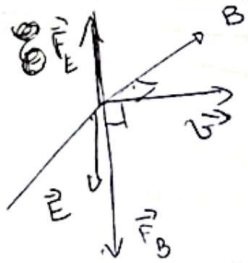


$$\vec{F}_B = q\,\vec{v}\times\vec{B}$$

$-e$

$\downarrow F_B$





Se $F_E = F_B \Rightarrow$ q não sofre desvio

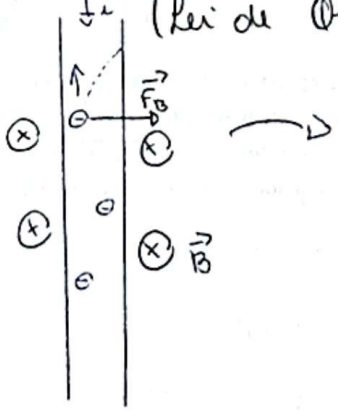
$$qE = q|\vec{v}\times\vec{B}|$$

$$qE = q\,v\cdot B \Rightarrow B = \frac{E}{v}$$

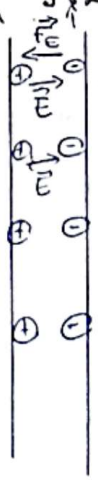
ou ainda (melhor)

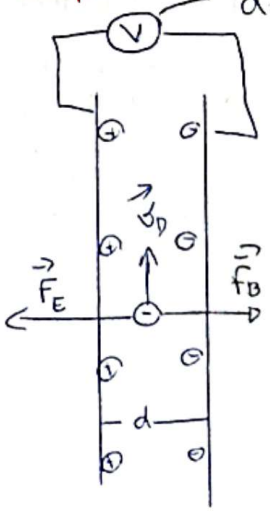
$$v = \frac{E}{B}$$

- Efeito Hall (1879) Verifican os portadores de carga dpH Maxwell 1864 (Lei de Ohm 1827)



fio





diferença de Potencial de Hall

$$\Delta V = \int E\,ds$$

$$\Rightarrow \boxed{V = Ed}$$

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Como vimos $v_D = \frac{E}{B}$ (igualando as forças)

mas, no cap. anterior (26)

$$v_D = \frac{J}{ne} = \frac{i}{neA}$$

↳ # de portadores de carga / volume.

⇒ Podemos obtivemos o valor de n:

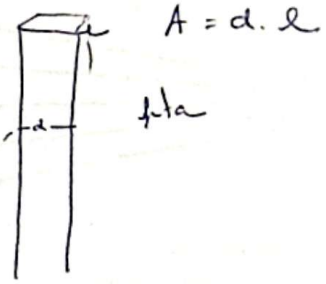
$$\frac{E}{B} = \frac{i}{neA} \Rightarrow n = \frac{iB}{eAE}$$

em termos de $V = E.d$

$$n = \frac{iB}{eAV}.d$$

$$\Rightarrow \boxed{n = \frac{iB}{eLV}}$$

espessura da fita



(não)

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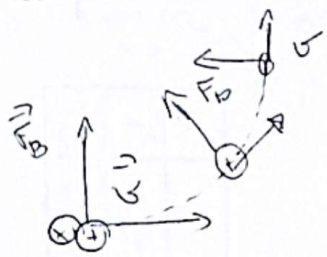
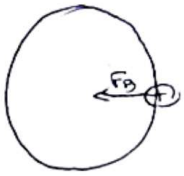
• Se $\vec{v} \parallel \vec{B} \Rightarrow$ MRU

28.9

Partícula carregada × movimento circular



$\Rightarrow$



$|v| = cte$

$F_B = \frac{mv^2}{r}$

$\vec{v} \perp \vec{B}$

$|q||\vec{v} \times \vec{B}| = \frac{mv^2}{r}$

$|q|\cancel{v}B = m\frac{v^{\cancel{2}}}{r}$

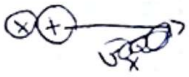
(Cíclotron e ~~síncrotron~~ síncrotron)

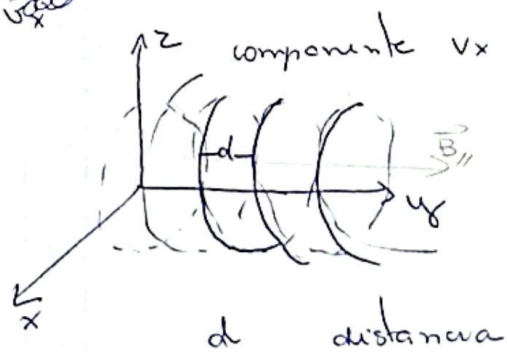
$\Rightarrow \boxed{r = \frac{mv}{|q|B}}$

• T → período $\quad v = \frac{\Delta S}{\Delta t} = \frac{2\pi r}{T}$

$\Rightarrow T = \frac{2\pi r}{v} = \frac{2\pi m v}{v|q|B} = \frac{2\pi m}{|q|B}$

• Se $\vec{v} = \vec{v}_x + \vec{v}_y$ e $\vec{v}_x \perp \vec{B}$ e $\vec{v}_y \parallel \vec{B}$





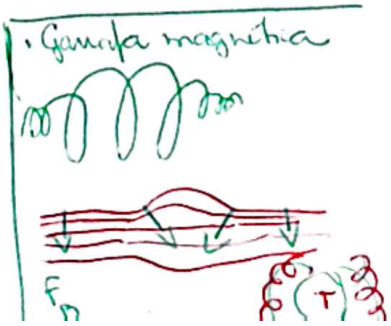
$T = \frac{2\pi m}{|q|B}$

cinturão de radiação de Van Allen → auroras polares

d distância entre as espiras

$v_y = \frac{\overset{d}{\Delta y}}{\Delta t} \Rightarrow d = v_y T$

• Garrafa magnética



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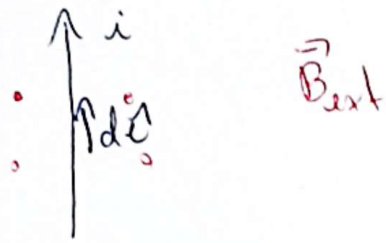
Força em um fio:



$$\vec{F}_B = q\vec{v} \times \vec{B}$$

$$d\vec{F}_B = dq\,\vec{v}_D \times \vec{B}$$

$$i = \frac{dq}{dt} \Rightarrow dq = i\,dt \qquad \vec{v}_D = \frac{d\vec{\ell}}{dt}$$

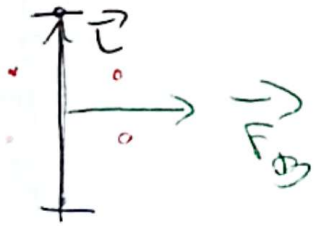
$$\Rightarrow d\vec{F}_B = i\,dt\,\frac{d\vec{\ell}}{dt} \times \vec{B}$$

$$d\vec{F}_B = i\,d\vec{\ell} \times \vec{B}$$

$$\vec{F}_B = \int d\vec{F}_B = \int i\,d\vec{\ell} \times \vec{B}$$

se todos elementos são constantes:

$$\vec{F}_B = i\vec{L} \times \vec{B}$$



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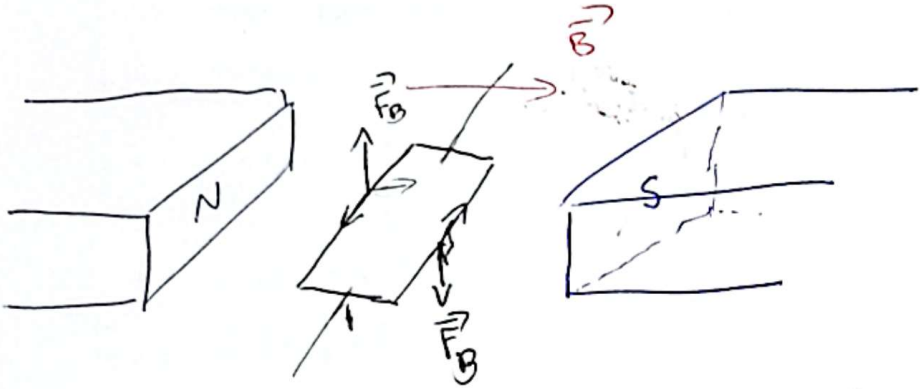
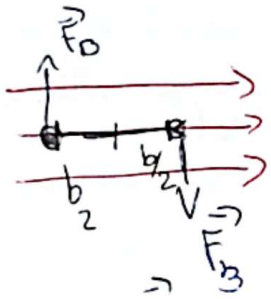
fica em uma espira

espira quadrada



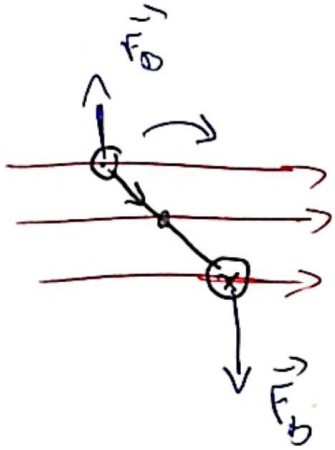


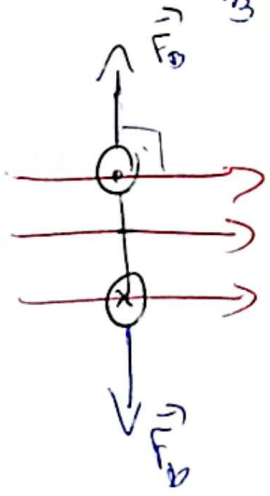
De frente



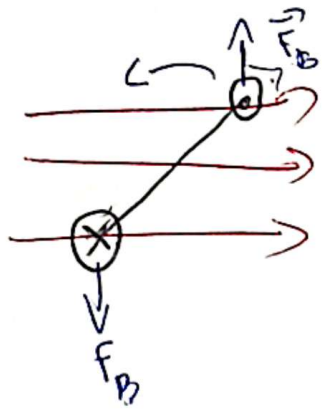
$\vec{B}$

⇒ giro ↷





Inercia



⇒ giro ↶

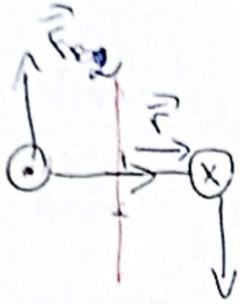
⇒ a espira oscila.

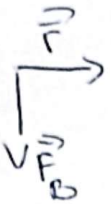
Podemos calcular o Torque:

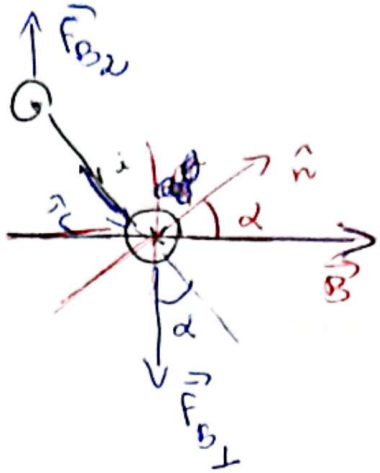
$$\vec{\tau} = \vec{r} \times \vec{F}$$



Digitalizado com CamScanner









$\vec{\tau} = 2\vec{\tau}_1$

$= 2\vec{r} \times \vec{B}$

$= 2\vec{r} \times i\vec{L} \times \vec{B}_{ext}$

$= \underbrace{2\vec{r} \times i\vec{L}}_{\vec{\mu}} \times \vec{B}_{ext}$

$\vec{\tau}_1 = \vec{r} \times \vec{F}_{B_1}$

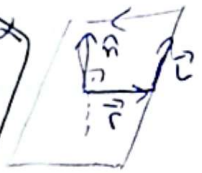
$\vec{\tau}_T = 2\vec{\tau}_1$

$\tau_T = 2|\vec{r}||\vec{F}_B| \operatorname{sen}\alpha$

$\downarrow$

$\frac{b}{2}$

$\tau_T = b|\vec{F}_B| \operatorname{sen}\alpha$



$\vec{F}_B = i\vec{L} \times \vec{B}$

$|\vec{F}_B| = i|\vec{L}||\vec{B}| \underbrace{\operatorname{sen}\theta}_{1}$

$\downarrow$

a

$\vec{\tau} = 2|\vec{r}|\, i\, |\vec{L}|\, \hat{n} \times \vec{B}_{ext}$

$= 2\frac{b}{2} i\, a\, \hat{n} \times B_{ext}$

$\vec{\tau} = \underbrace{i\, ab\, \hat{n}}_{\vec{\mu}} \times \vec{B}_{ext}$

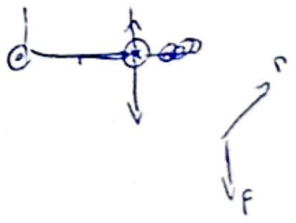
$\tau_T = i\, ab\, |\vec{B}| \operatorname{sen}\alpha$

$\downarrow$

Área.

↳ ângulo entre a normal da espira e o campo magnético.

- Se tivermos N espiras:



$\tau_{TN} = N\, \tau_{1\,espira}$

$T_{TN} = N i A_{área} B \operatorname{sen}\alpha$

$\downarrow$

μ → momento magnético da espira.

$T_{TN} = \mu B \operatorname{sen}\alpha$

$\vec{T}_{TN} = \vec{\mu} \times \vec{B}$



$\vec{\mu}$ segue a mão direita com a corrente

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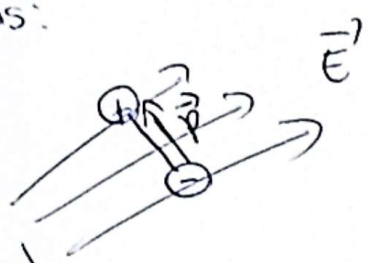
Vimos:

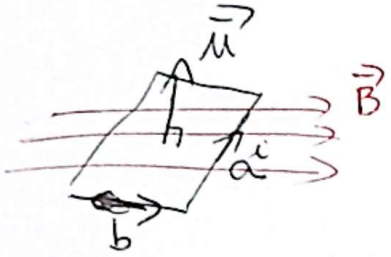
Água



(Dipolo elétrico)

$$\vec{\tau} = \vec{p} \times \vec{E}$$

$$U(\theta) = -\vec{p} \cdot \vec{E}$$

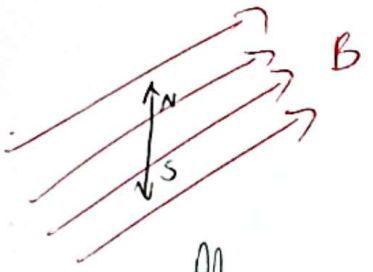


(Dipolo magnético)

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

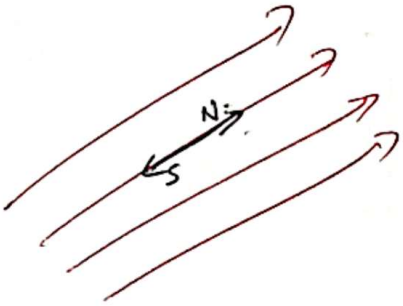
$$U(\theta) = -\vec{\mu} \cdot \vec{B}$$

A bussola:



agulha imantada

$\Rightarrow$



$\Rightarrow$ a espira funciona como um dipolo magnético.

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