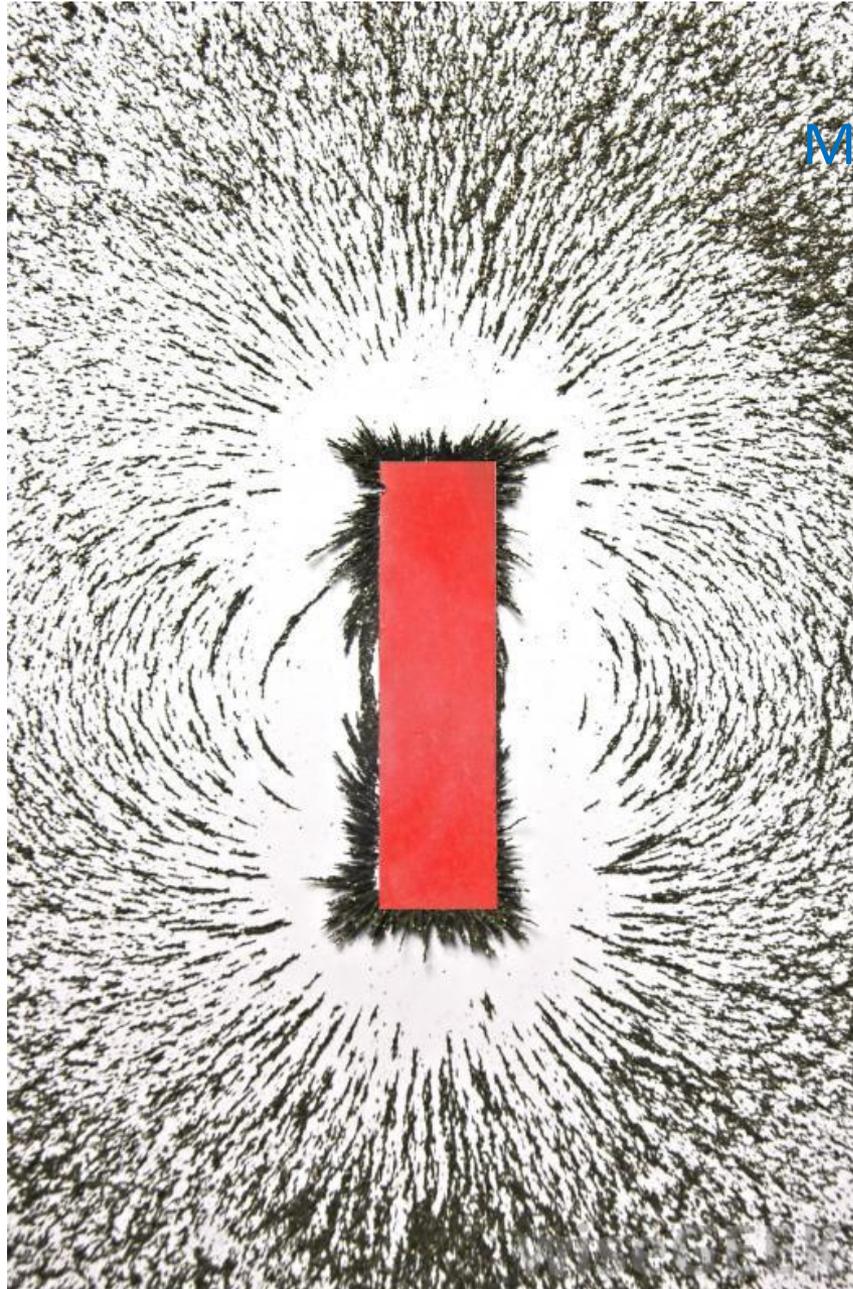


Campo Magnético 1



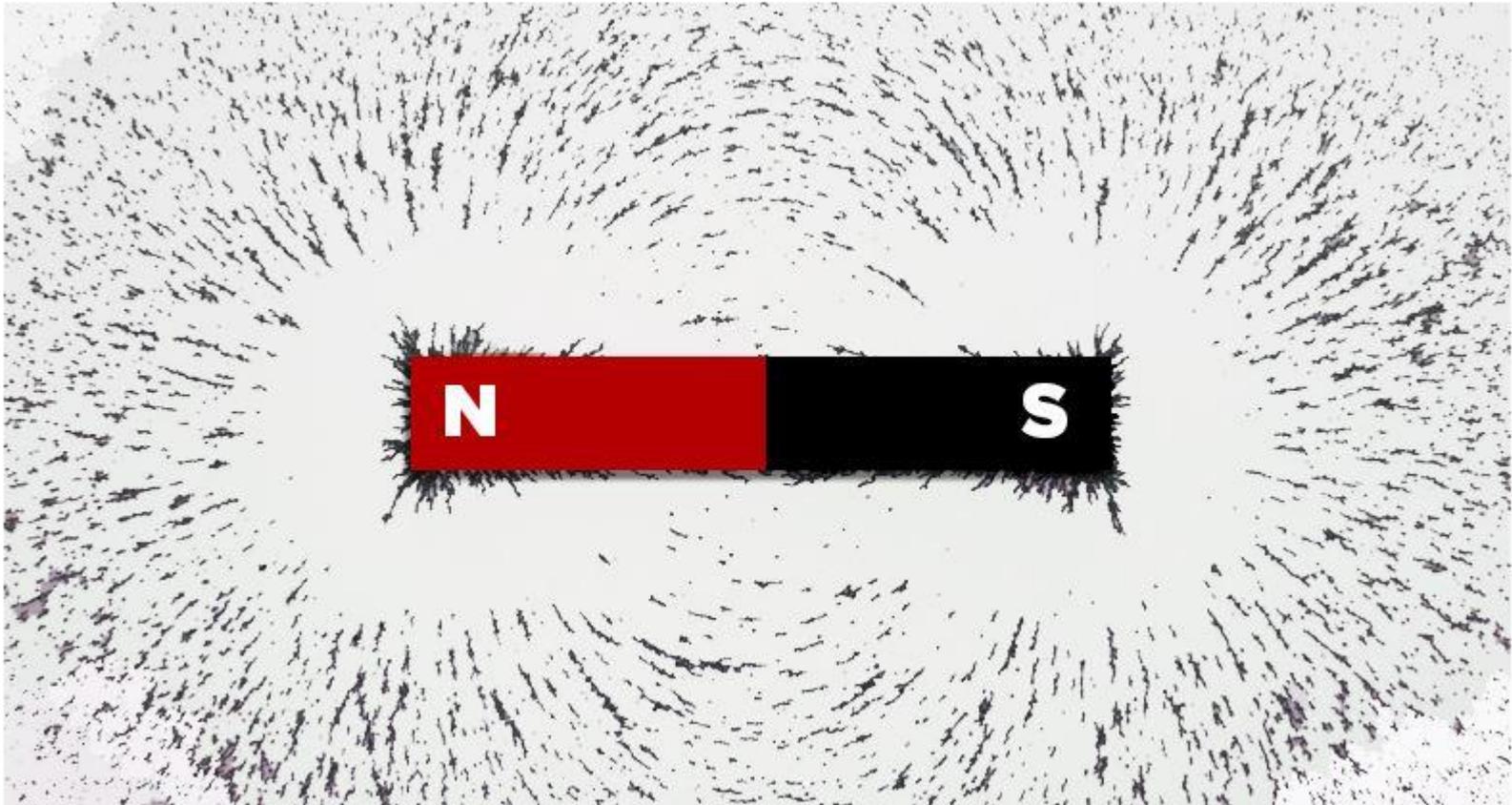
Magnetismo

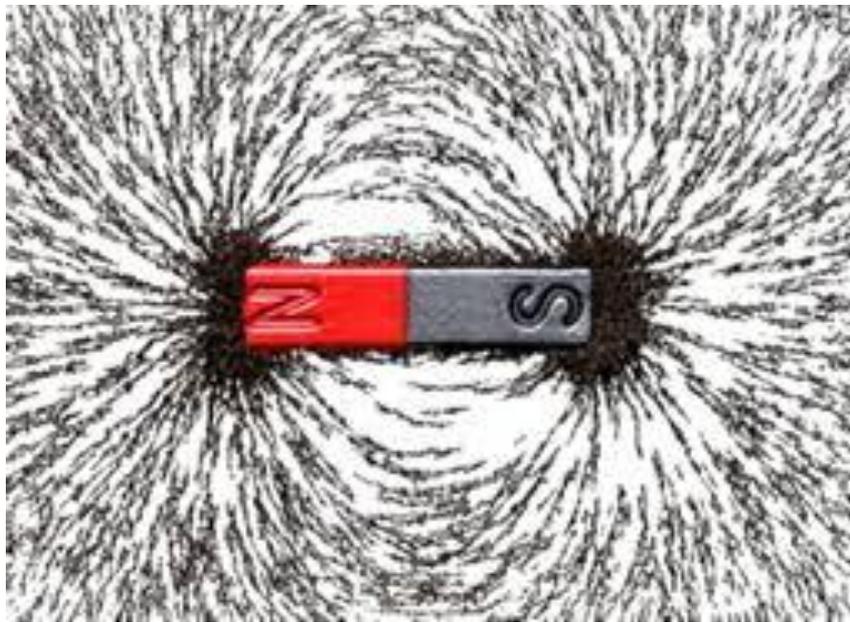


verificou-se que os pedaços de ferro eram atraídos mais intensamente em certas partes do ímã – os polos dos ímãs

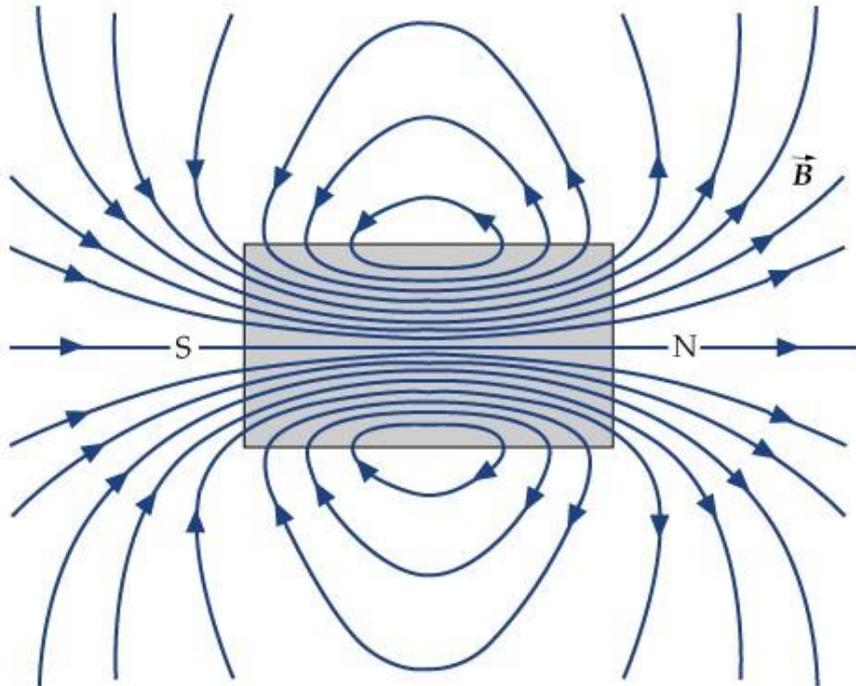
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verificou-se que os pedaços de ferro eram atraídos mais intensamente em certas partes do imã – os polos dos imãs.



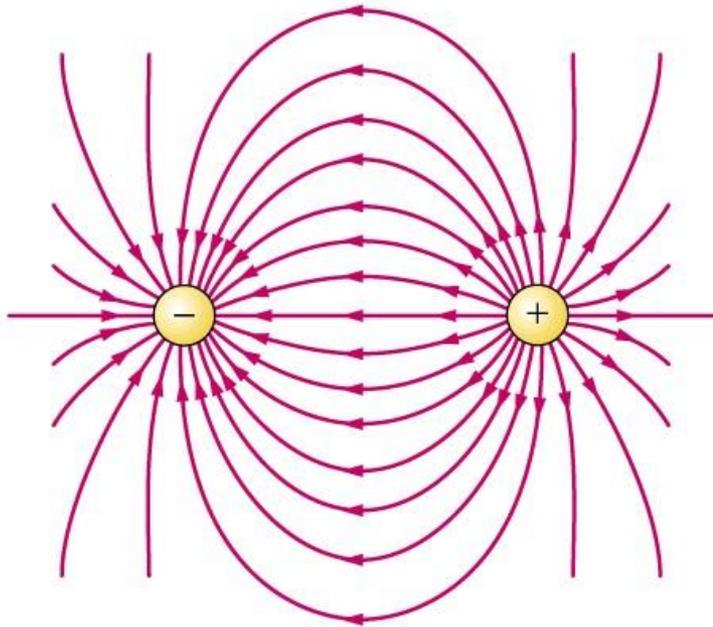


As linhas de indução ou linhas de campo indicam a direção do campo magnético \vec{B}

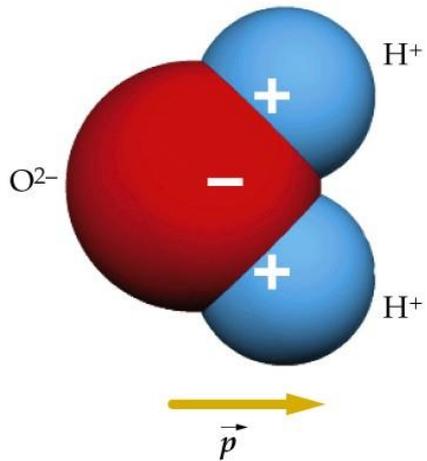


(a)

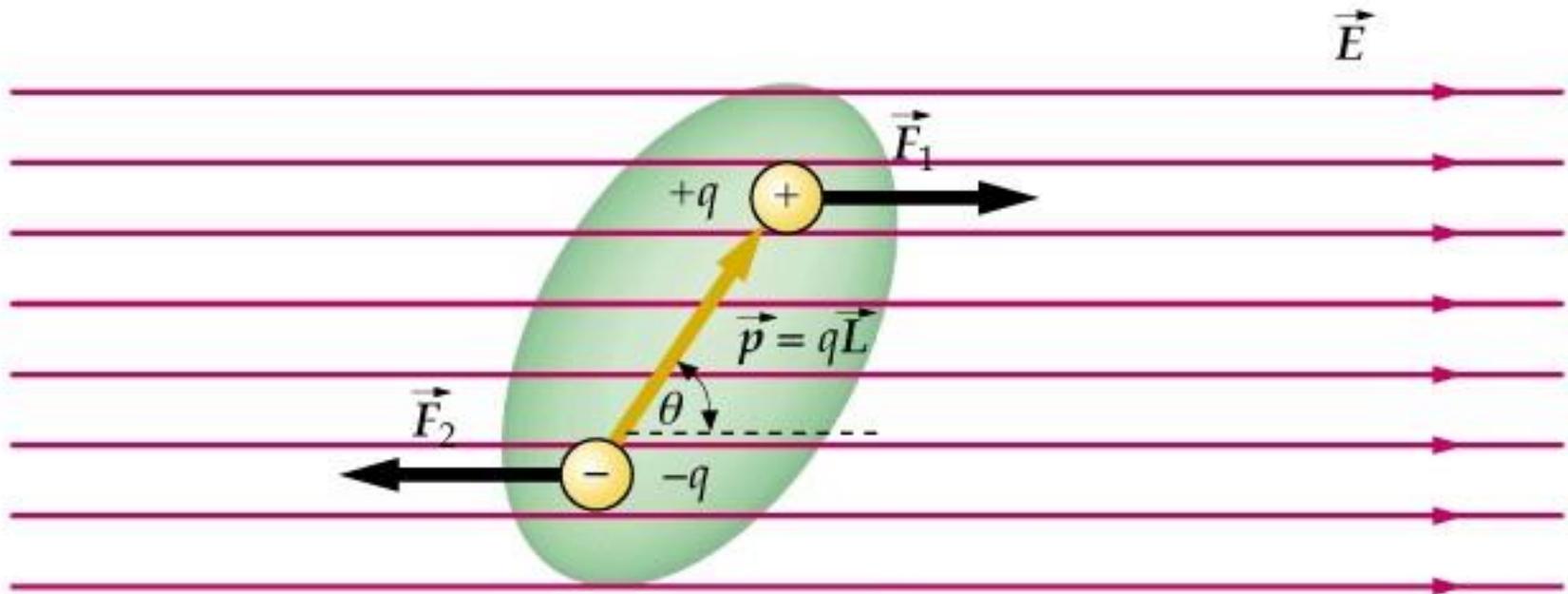
Dipolo Eléctrico



$$\vec{p} = q\vec{L}$$



Torque em um Dipolo elétrico em campo Uniforme

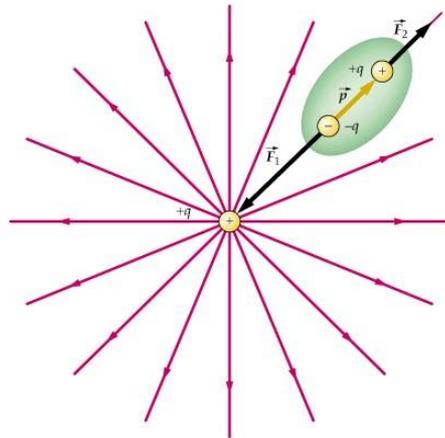


$$\vec{\tau} = \vec{p} \times \vec{E}$$

$$U = -\vec{p} \cdot \vec{E}$$

$$U = -p \cdot E \cdot \cos\theta$$

Força em campos NÃO Uniformes



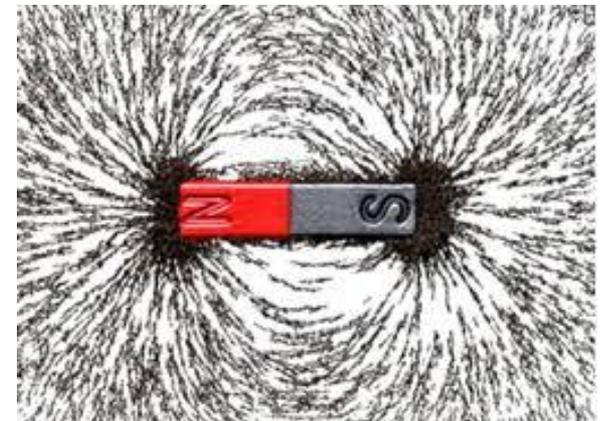
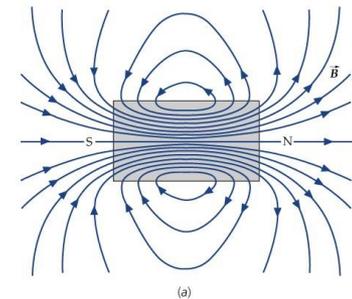
Um efeito similar ocorre com os dipolos magnéticos, o que explica porque a limalha de ferro se concentra nos pólos dos imãs

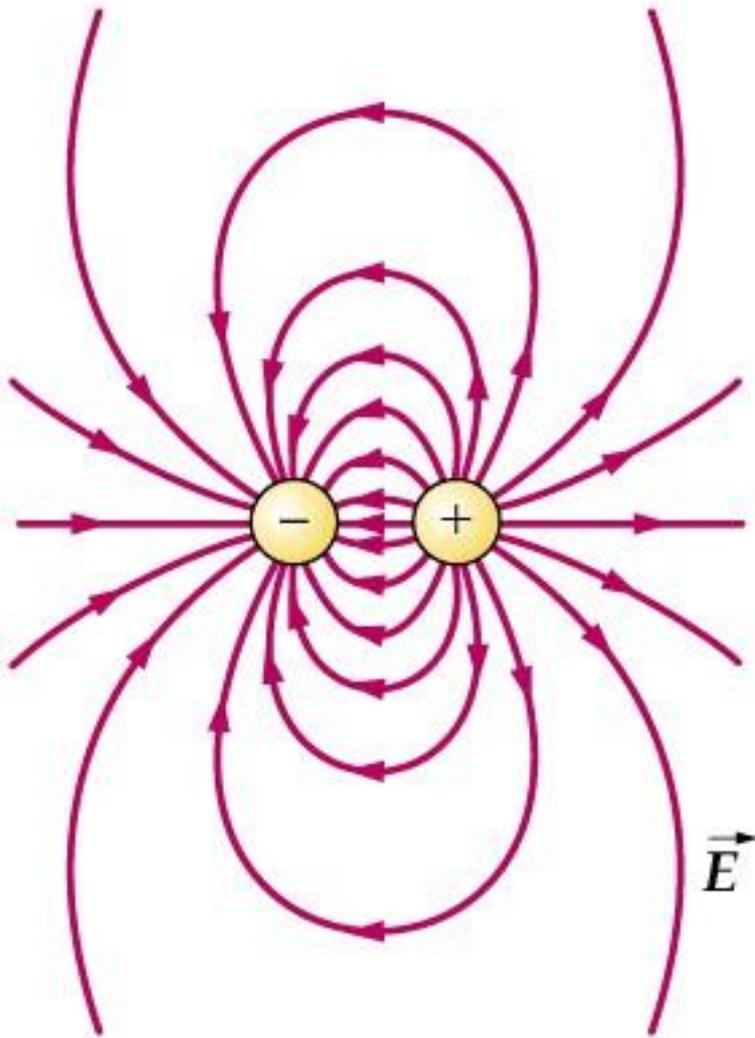
$$\vec{F} = \vec{\mu} \cdot \nabla \vec{B}$$

Força em um dipolo elétrico num Campo Elétrico não uniforme:

$$\vec{F} = \vec{p} \cdot \nabla \vec{E}$$

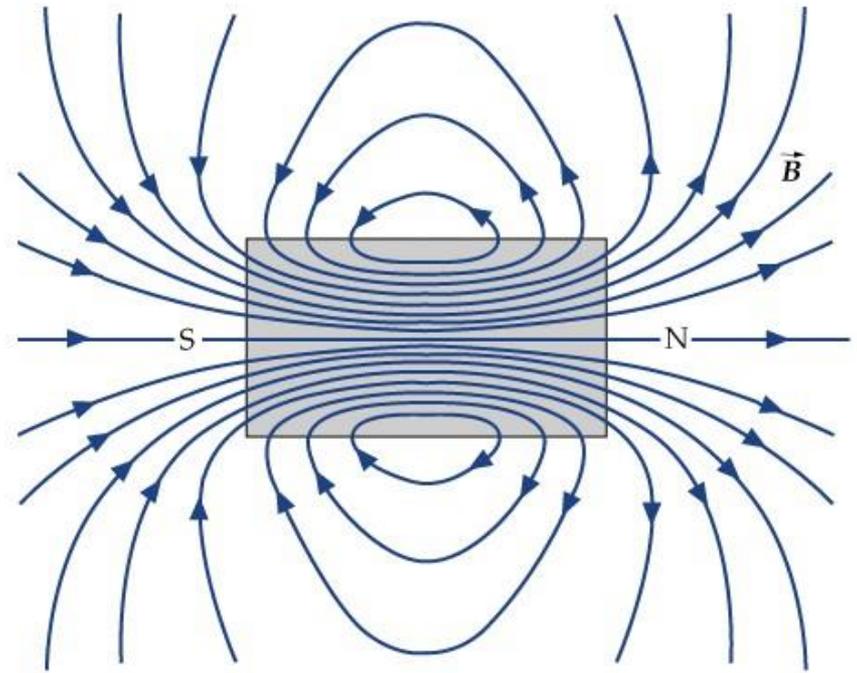
O dipolo elétrico é atraído para a região com maior gradiente ($\nabla \vec{E}$).





dipolo elétrico

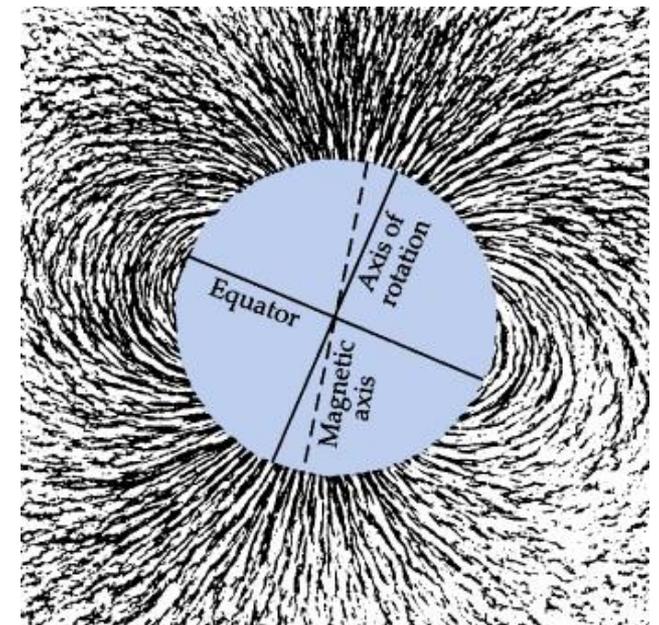
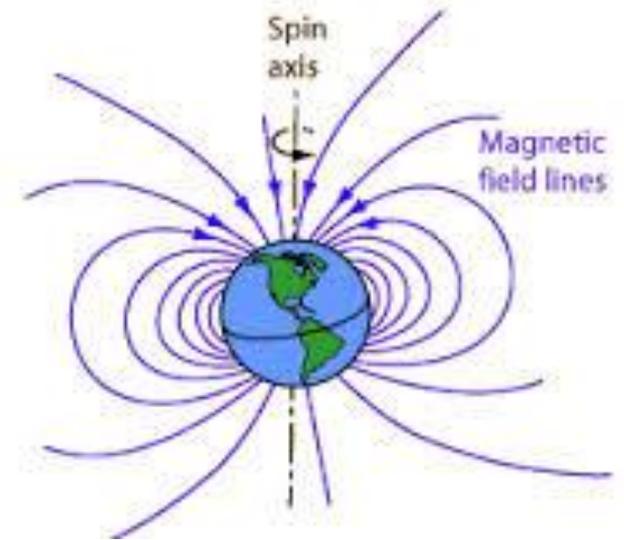
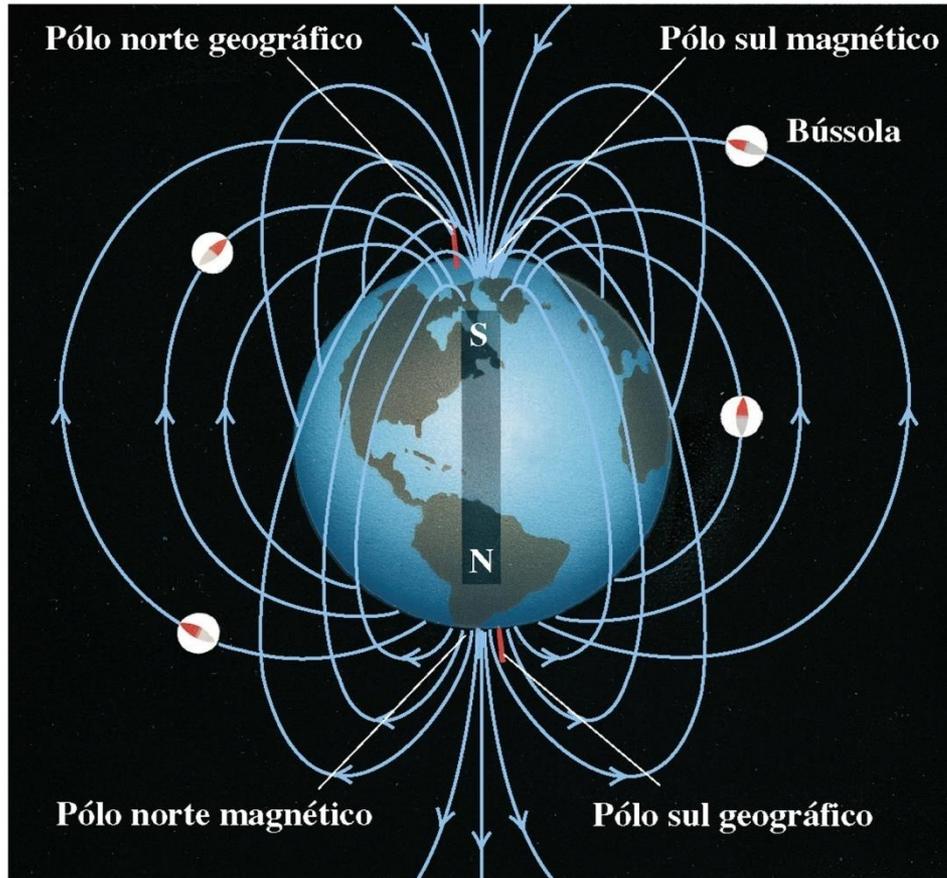
$$\vec{p} = q\vec{L}$$



(a)

dipolo magnético – é o limite em que o tamanho do ímã tende a zero

Campo Magnético da Terra



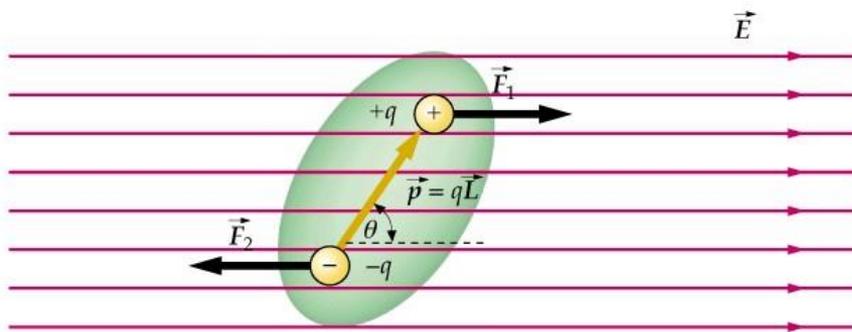
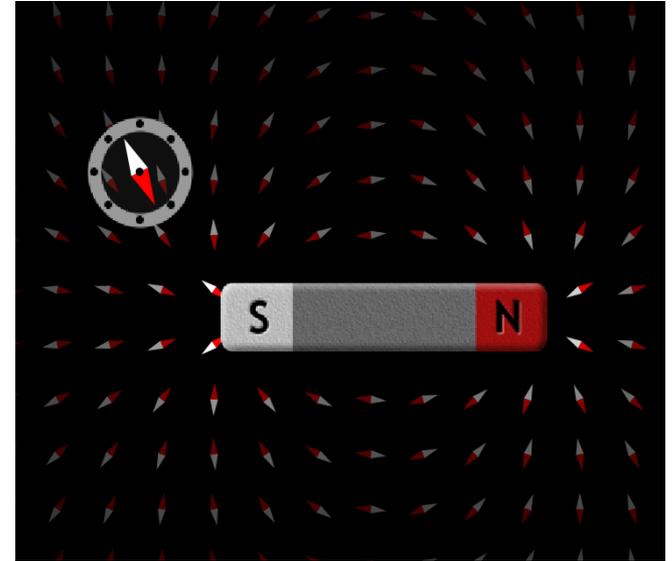
$$B_T \sim 0,2 \text{ G} = 2 \cdot 10^{-5} \text{ T} \text{ (São Carlos)}$$

Torque em Dipolo magnético



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

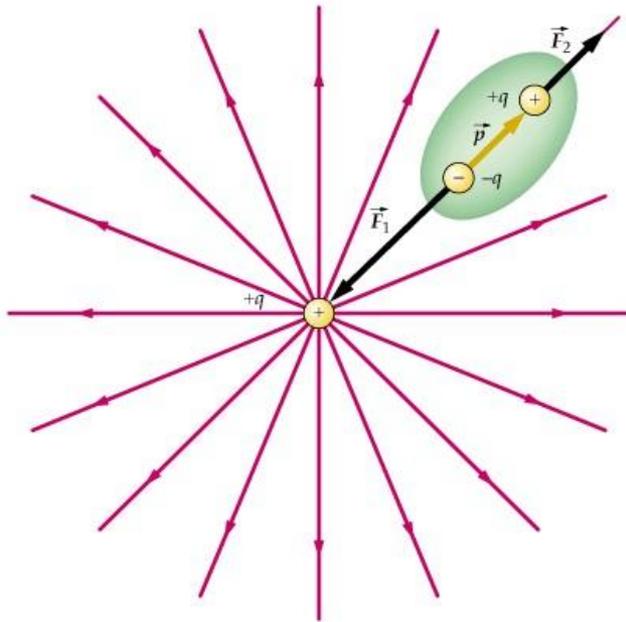
$$U = -\vec{\mu} \cdot \vec{B}$$



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

$$U = -p \cdot E \cdot \cos\theta$$

Força em Dipolo elétrico em campo NÃO Uniforme



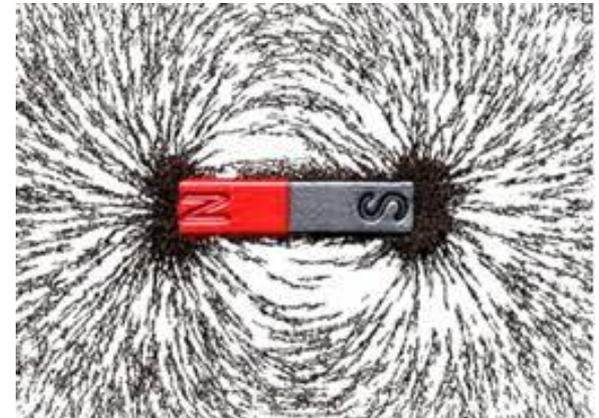
Força em um dipolo elétrico num Campo Elétrico não uniforme:

$$\vec{F} = \vec{p} \cdot \nabla \vec{E}$$

O dipolo elétrico é atraído para a região com maior gradiente ($\nabla \vec{E}$).

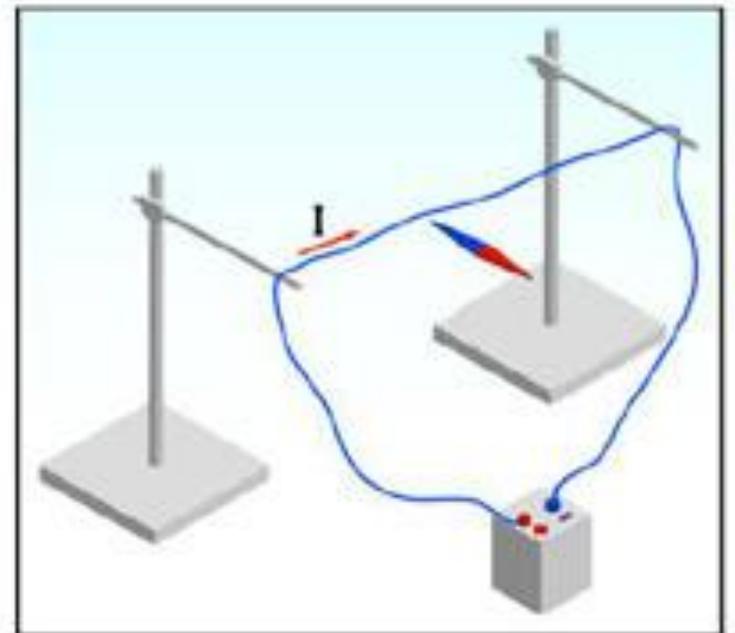
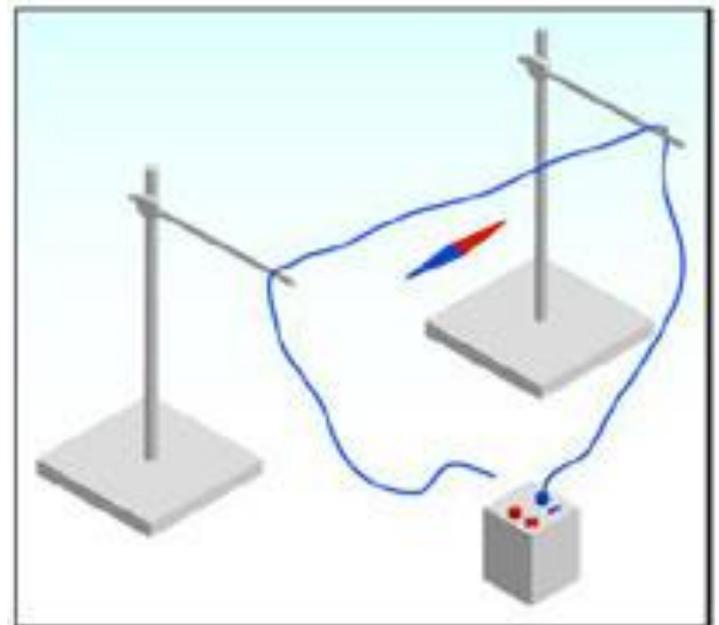
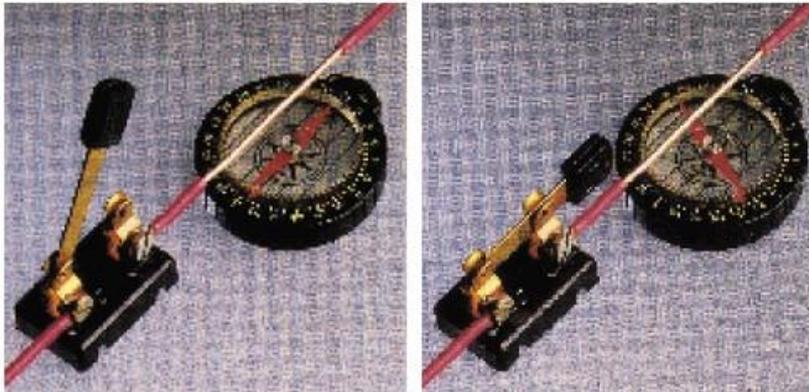
Um efeito similar ocorre com os [dipolos magnéticos](#), o que explica porque a limalha de ferro se concentra nos pólos dos imãs

$$\vec{F} = \vec{\mu} \cdot \nabla \vec{B}$$

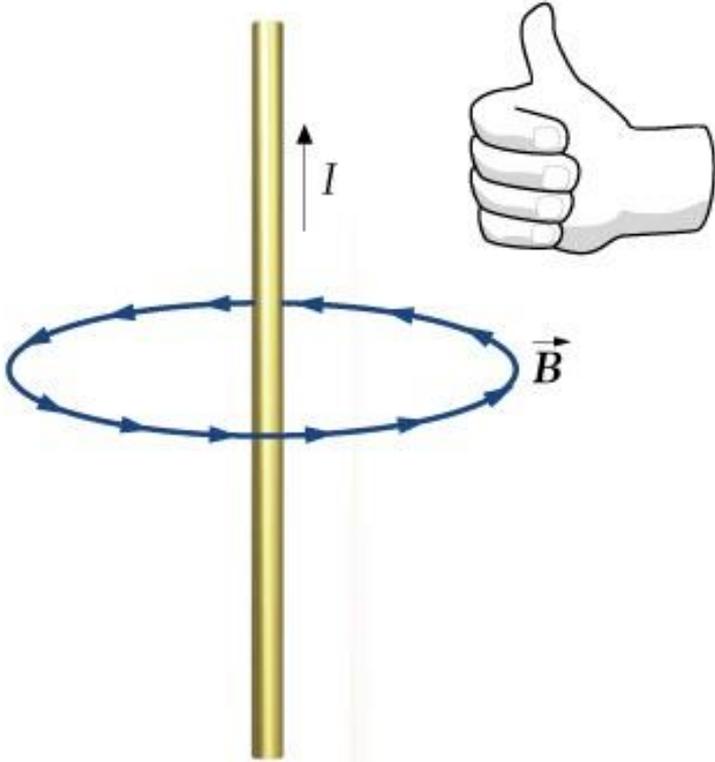


Fontes do Campo Magnético

Hans Christian Ørsted Dinamarca (1777 – 1851)



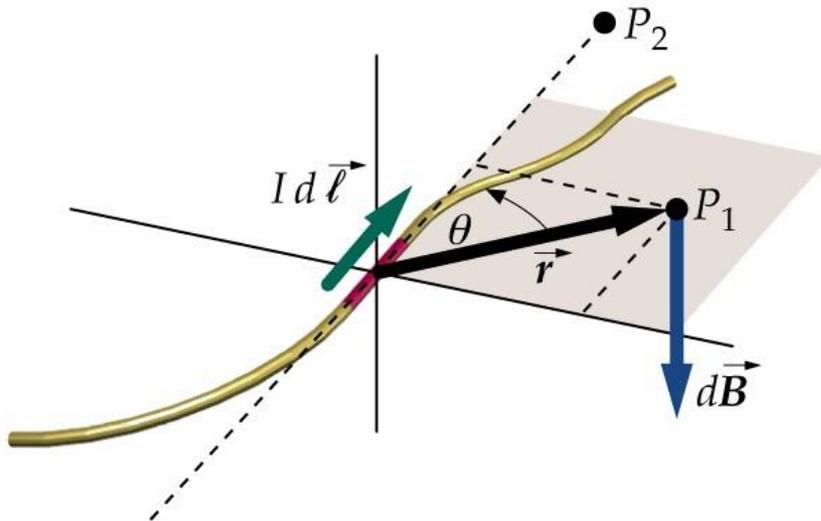
Campo Magnético devido a corrente em um fio infinito



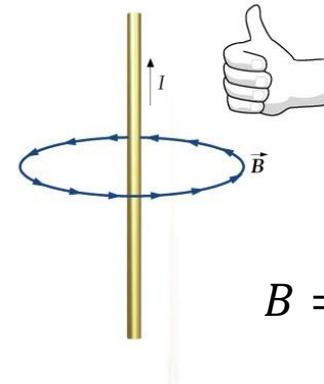
Campo magnético devido a um elemento de corrente

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

Lei de Biot - Savart



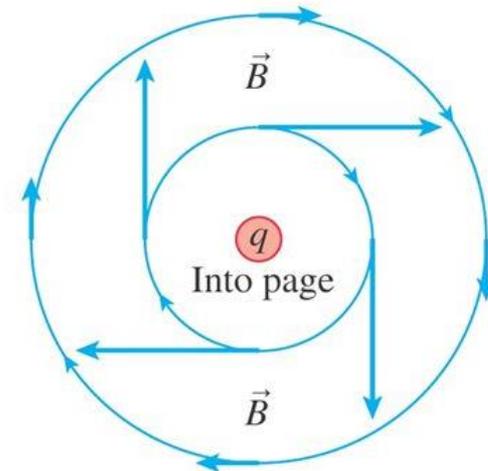
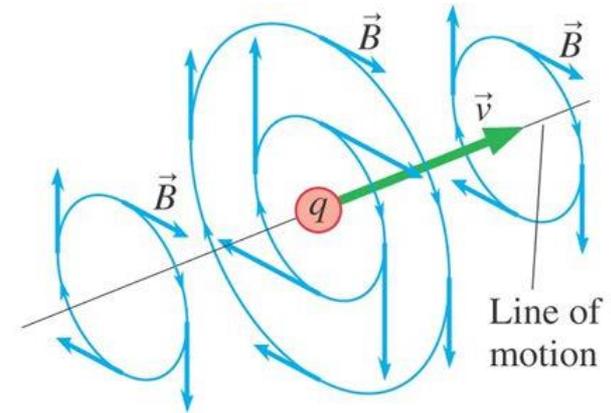
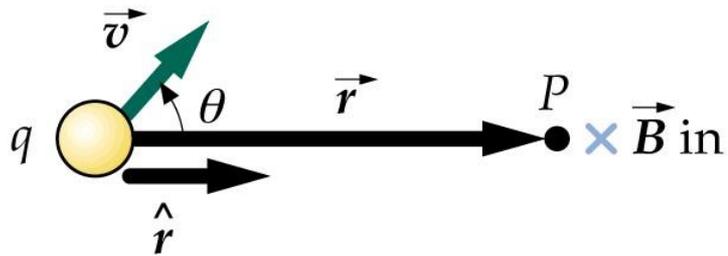
obs: que o campo gerado pelo elemento $d\vec{\ell}$ é nulo em P_2 , pois neste caso $d\vec{\ell} \parallel \hat{r}$ mas não é nulo em P_1 .



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

obs: no caso do fio retilíneo \vec{B} tem simetria circular.

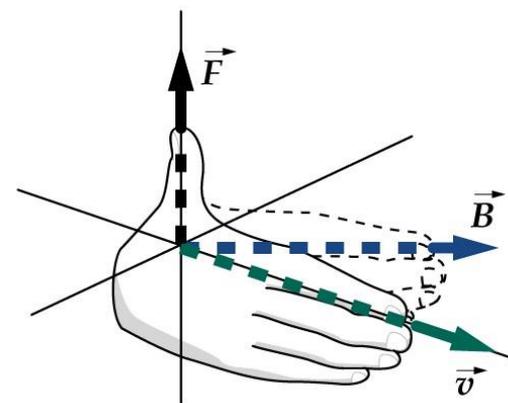
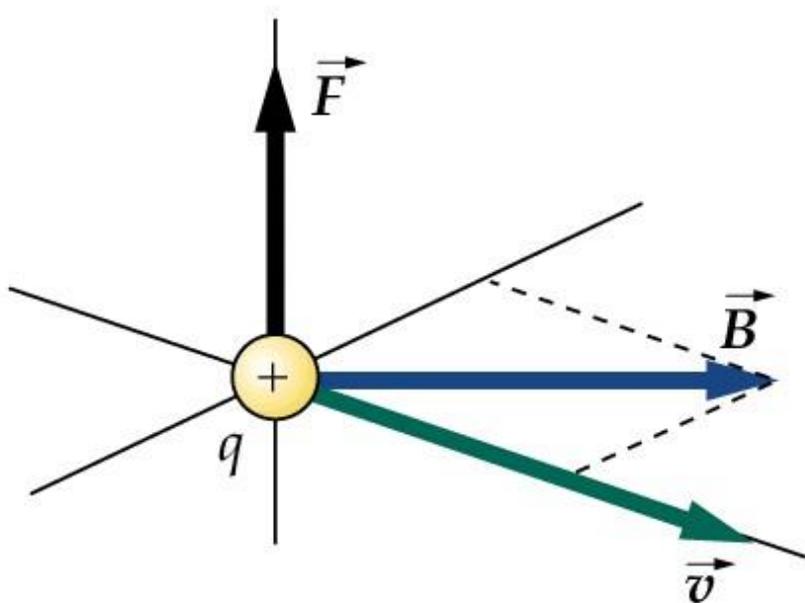
Campo magnético de uma carga em movimento



$$\vec{B} = \frac{\mu_0}{4\pi} q \vec{v} \times \vec{r}$$

Força Magnética em uma carga em movimento

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



Produto Vetorial

Regra da Mão Direita

Força Magnética em uma carga em movimento

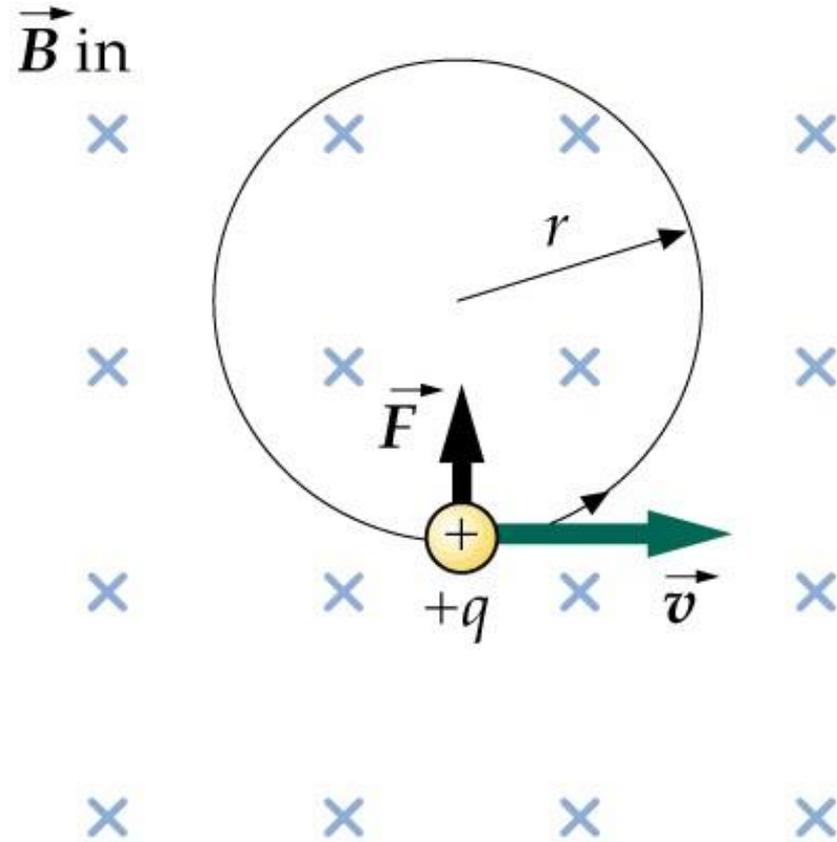
$$\vec{F} = q\vec{v} \times \vec{B}$$

⇓

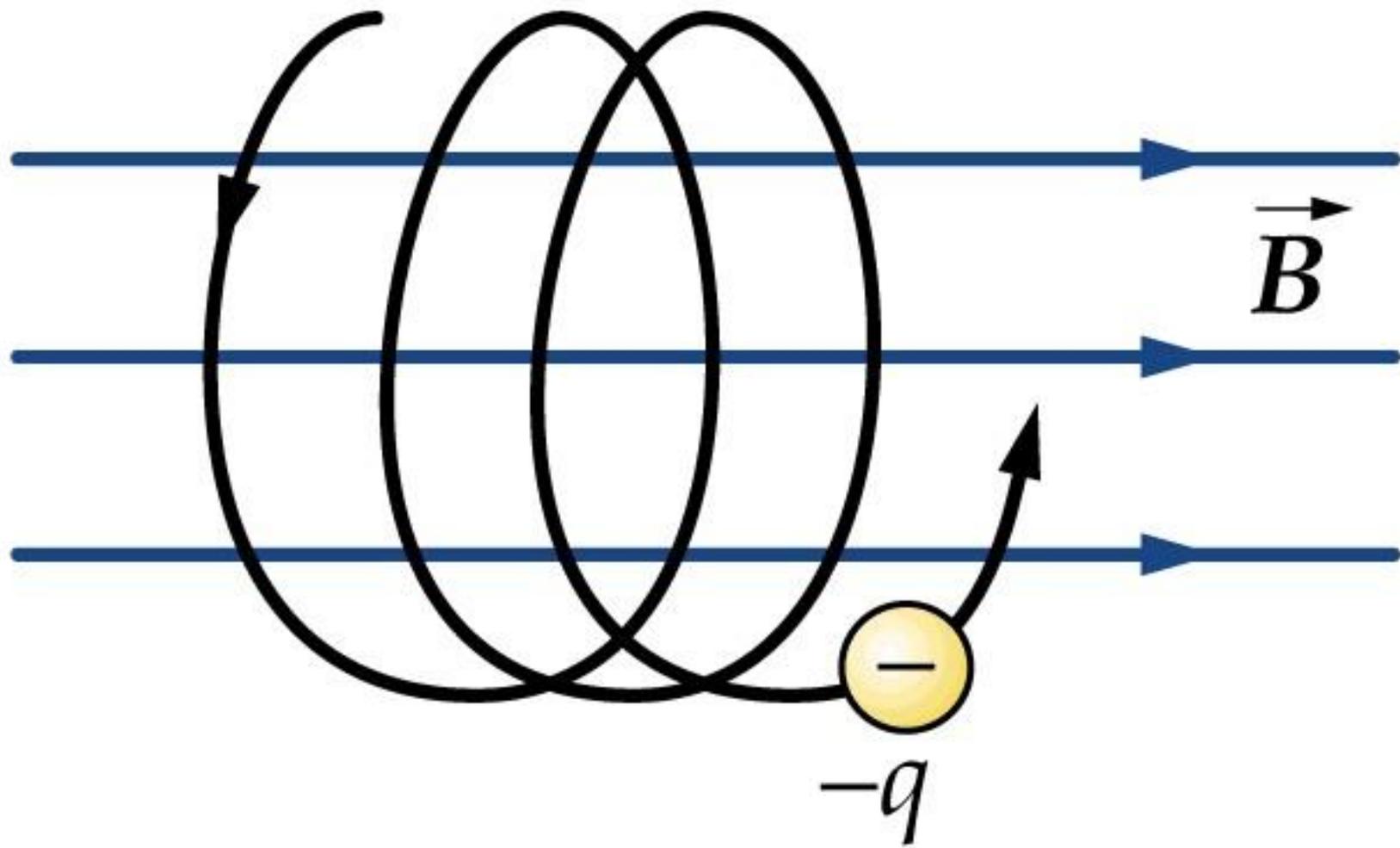
$$q \cdot v \cdot B = m \frac{v^2}{r}$$

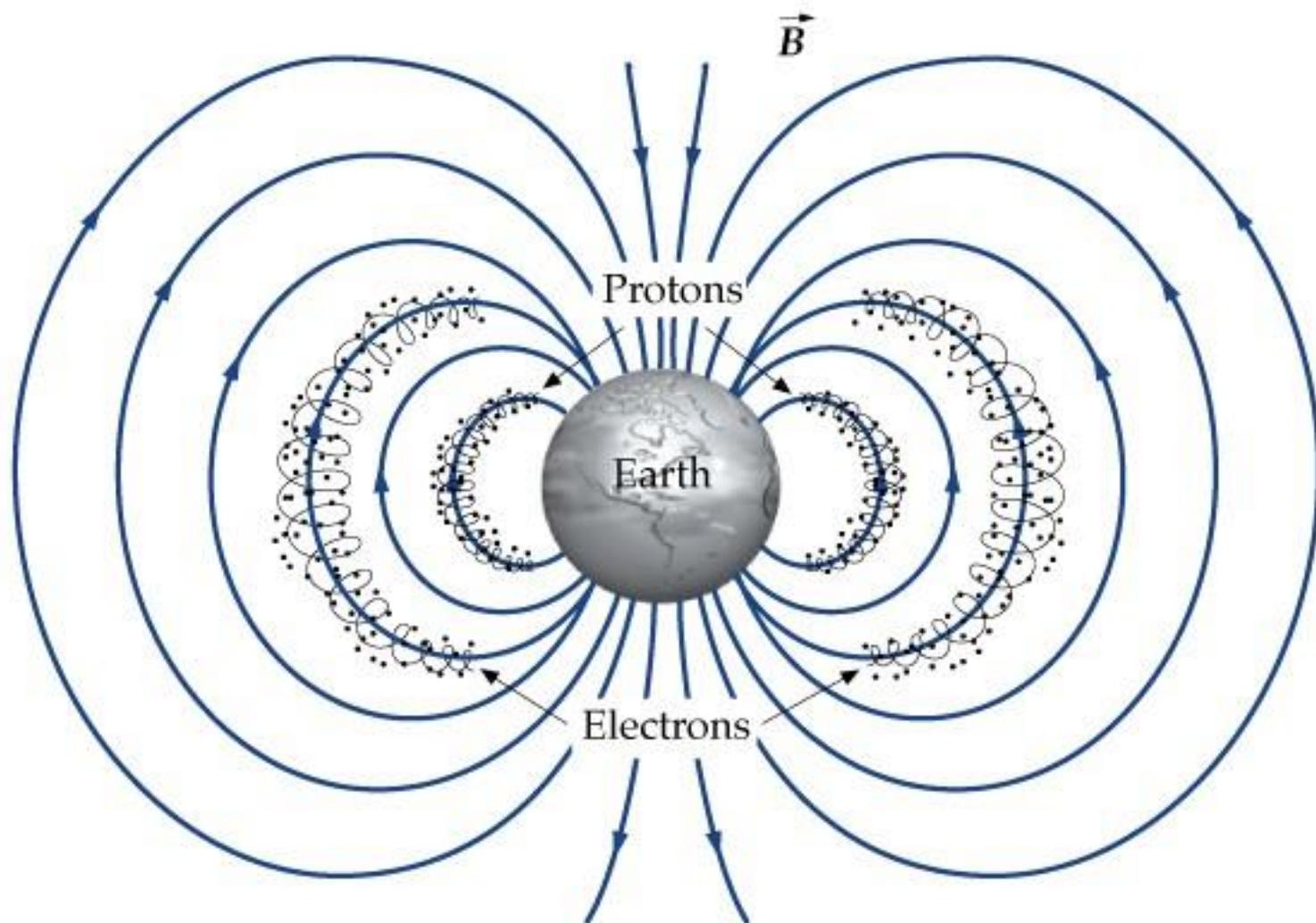
⇓

$$r = \frac{m \cdot v}{qB}$$

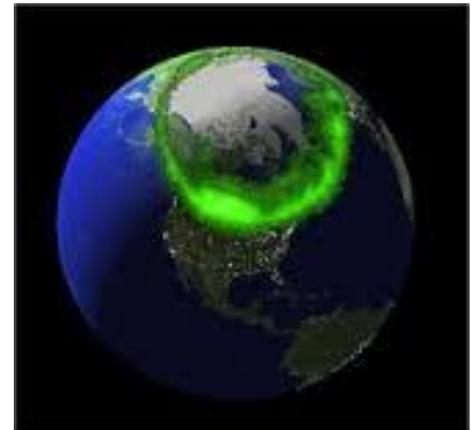
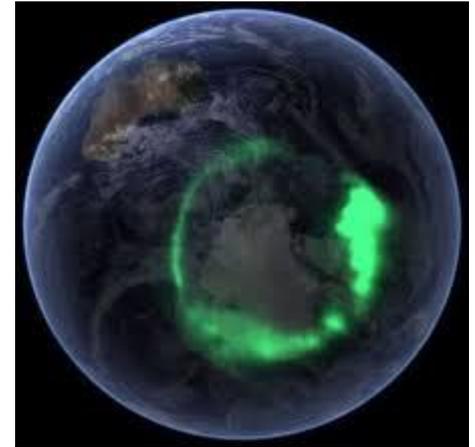


A força Magnética NÃO realiza trabalho → não altera a energia cinética

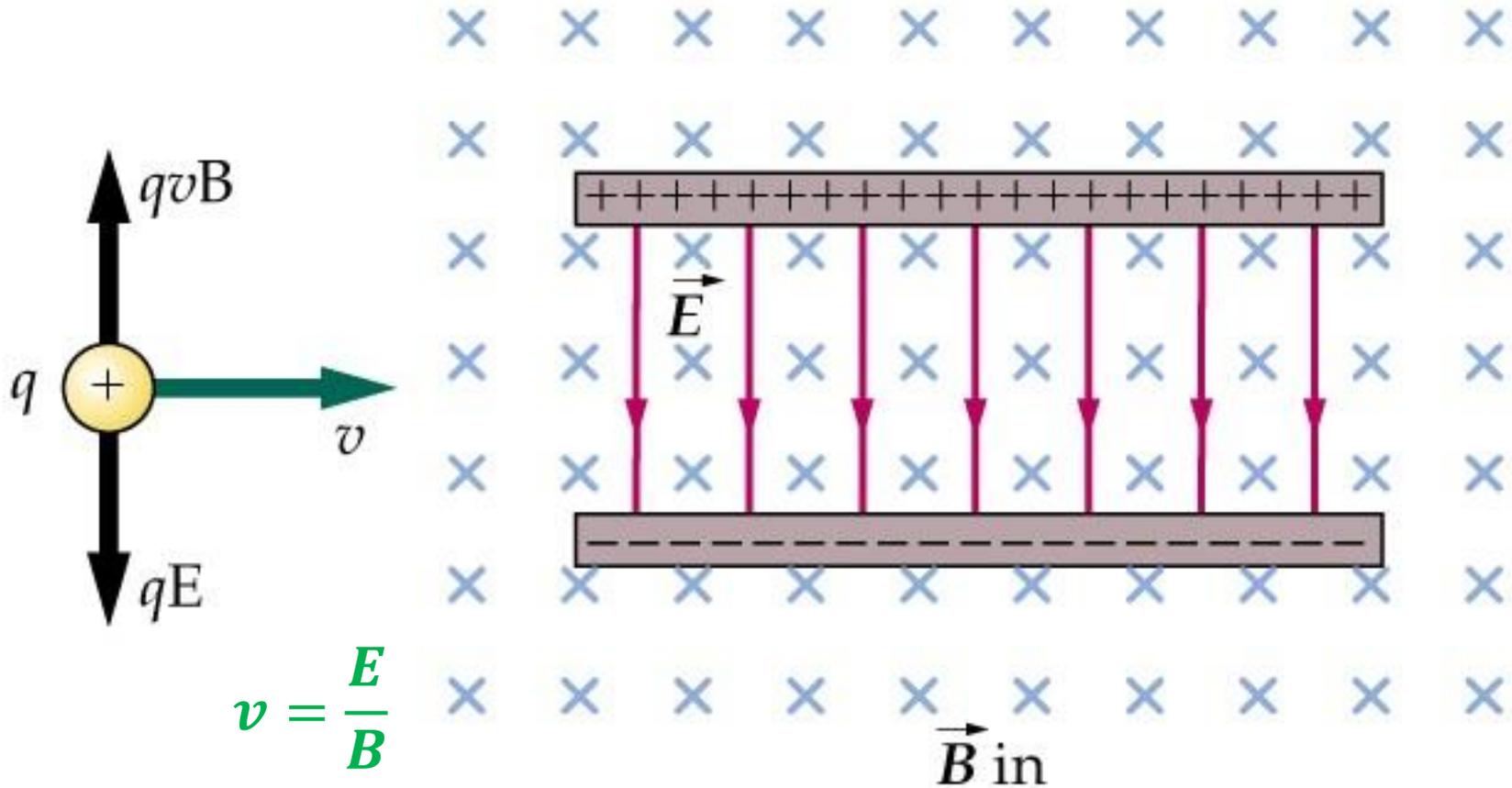




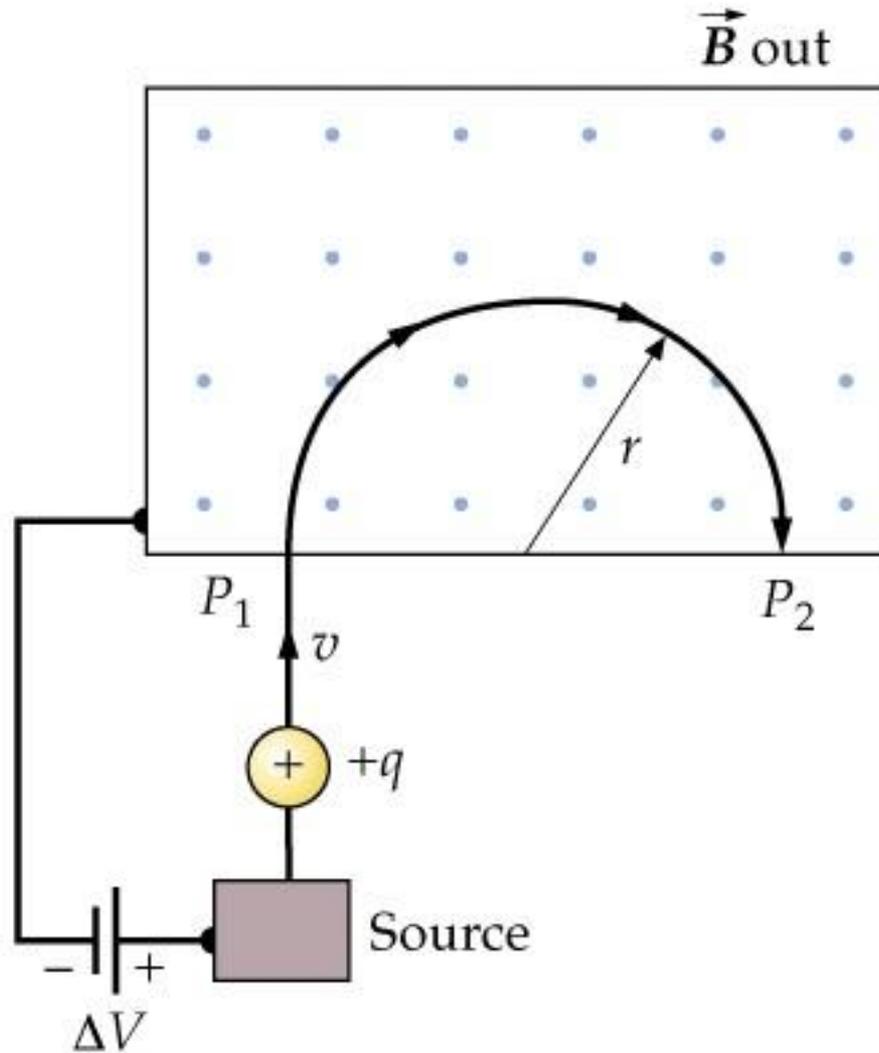




Seletor de Velocidades

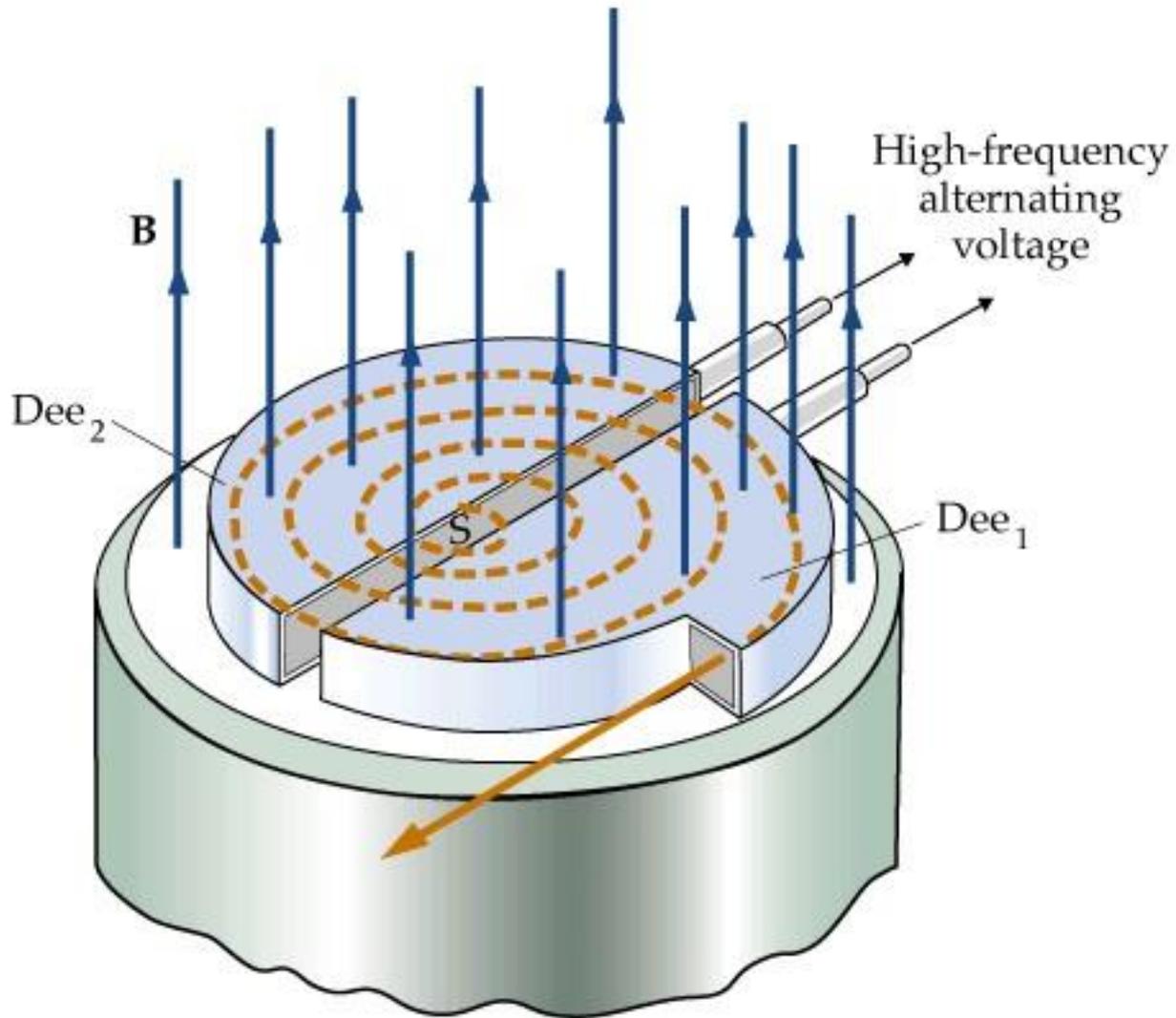


Espectrômetro de Massa

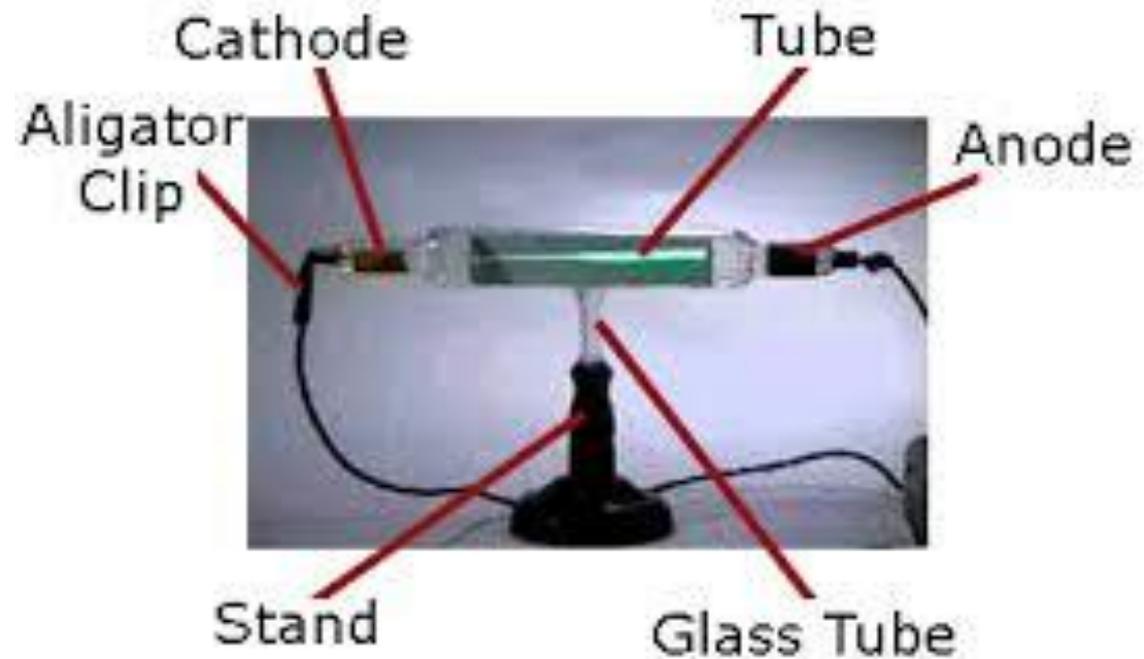


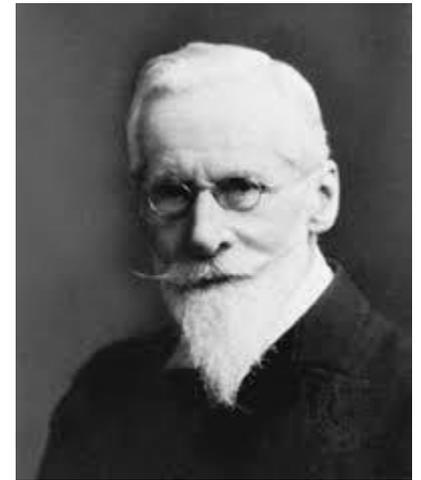
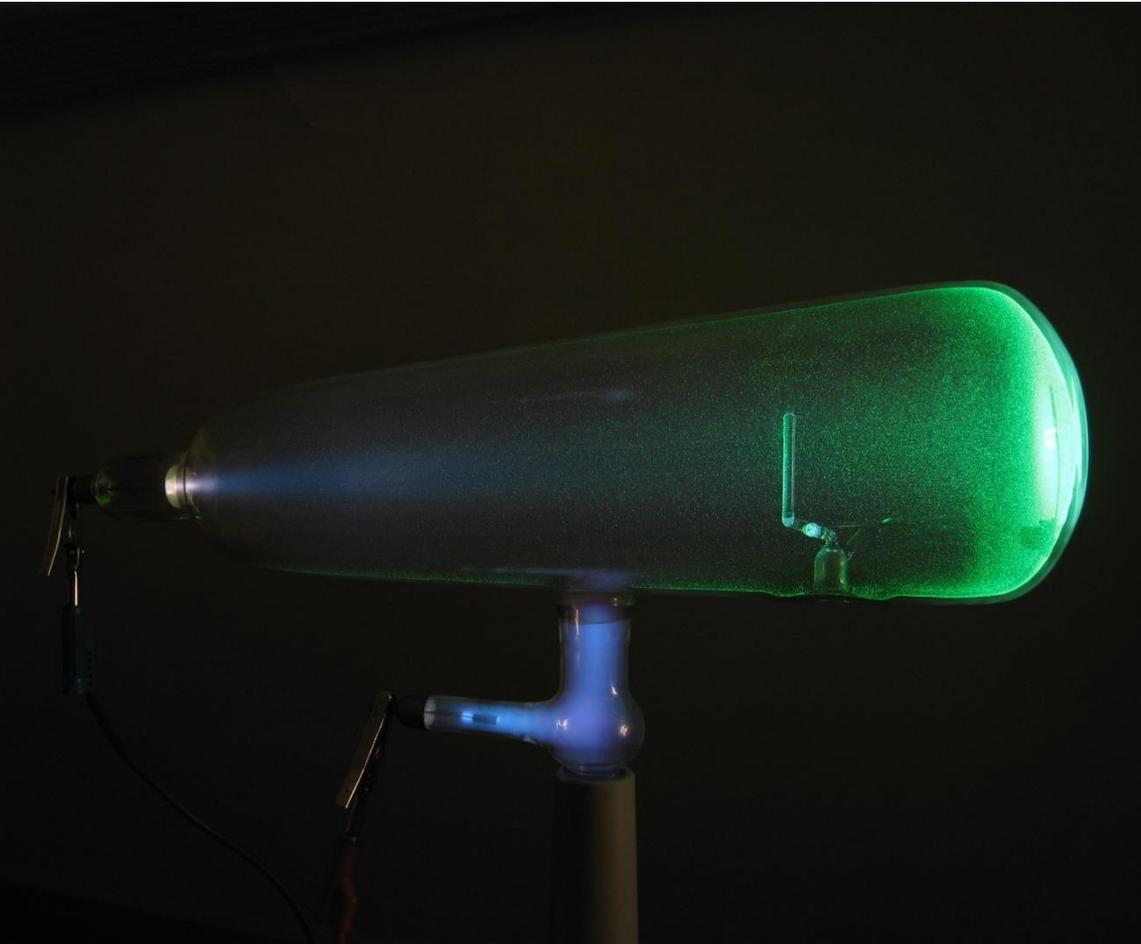
$$r = \frac{m \cdot v}{qB}$$

Cicloton

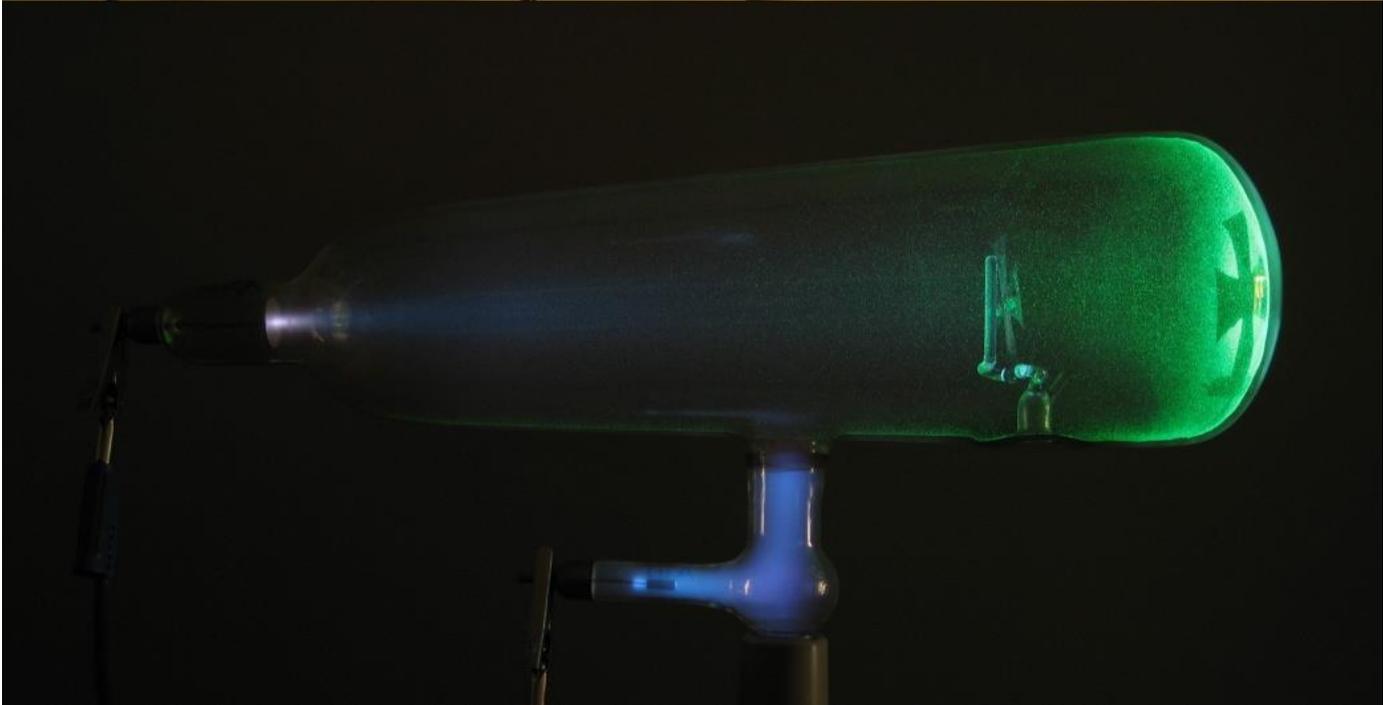
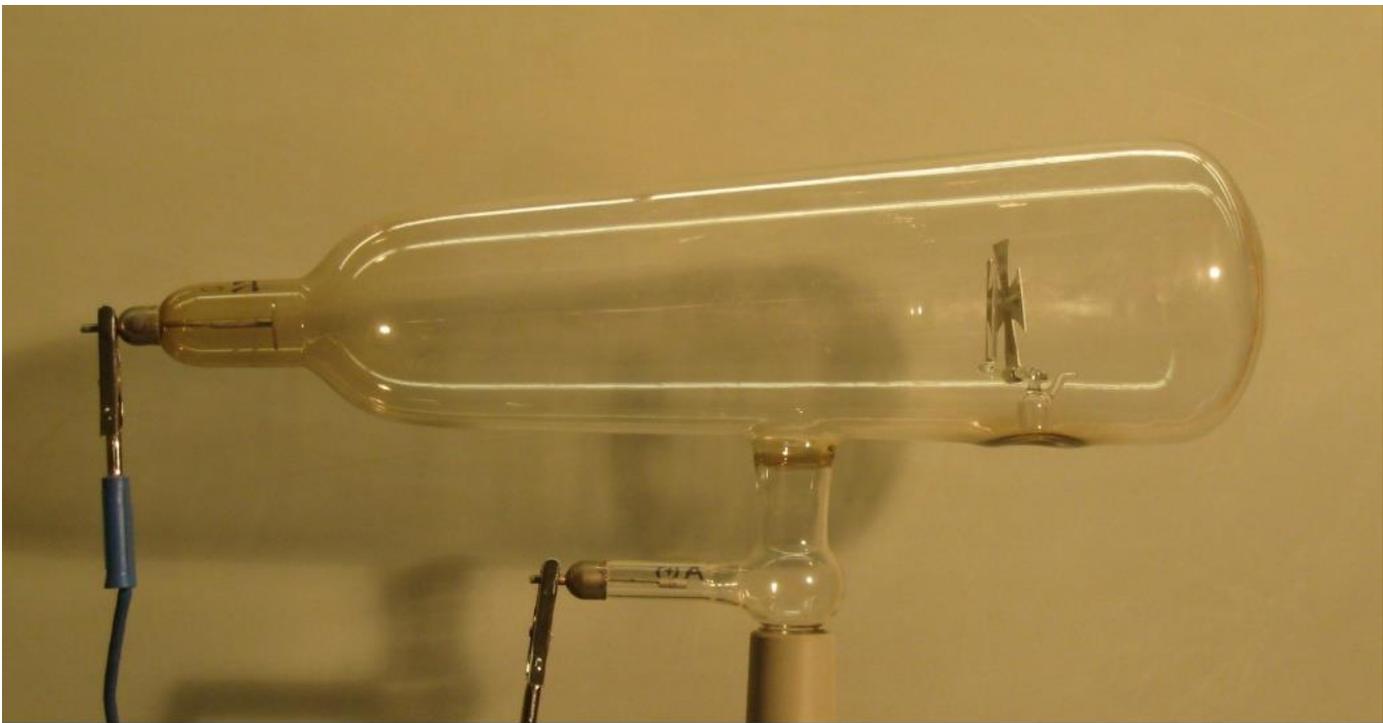


Raios Catódicos





Willian Crookes
Inglaterra (1832 – 1919)



Discovery of the Electron



J. J. Thomson

Inglaterra

(1856-1940)

In the 1890s scientists and engineers were familiar with “cathode rays.” These rays were generated from one of the metal plates in an evacuated tube with a large electric potential across it.

It was surmised that cathode rays had something to do with atoms.

It was known that cathode rays could penetrate matter and were deflected by magnetic and electric fields.

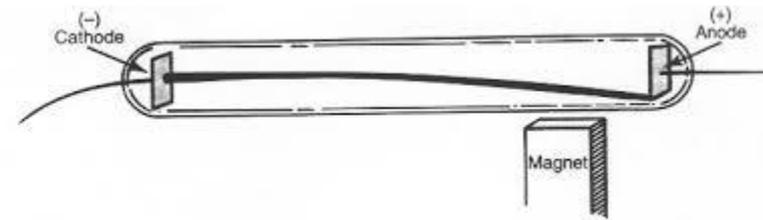
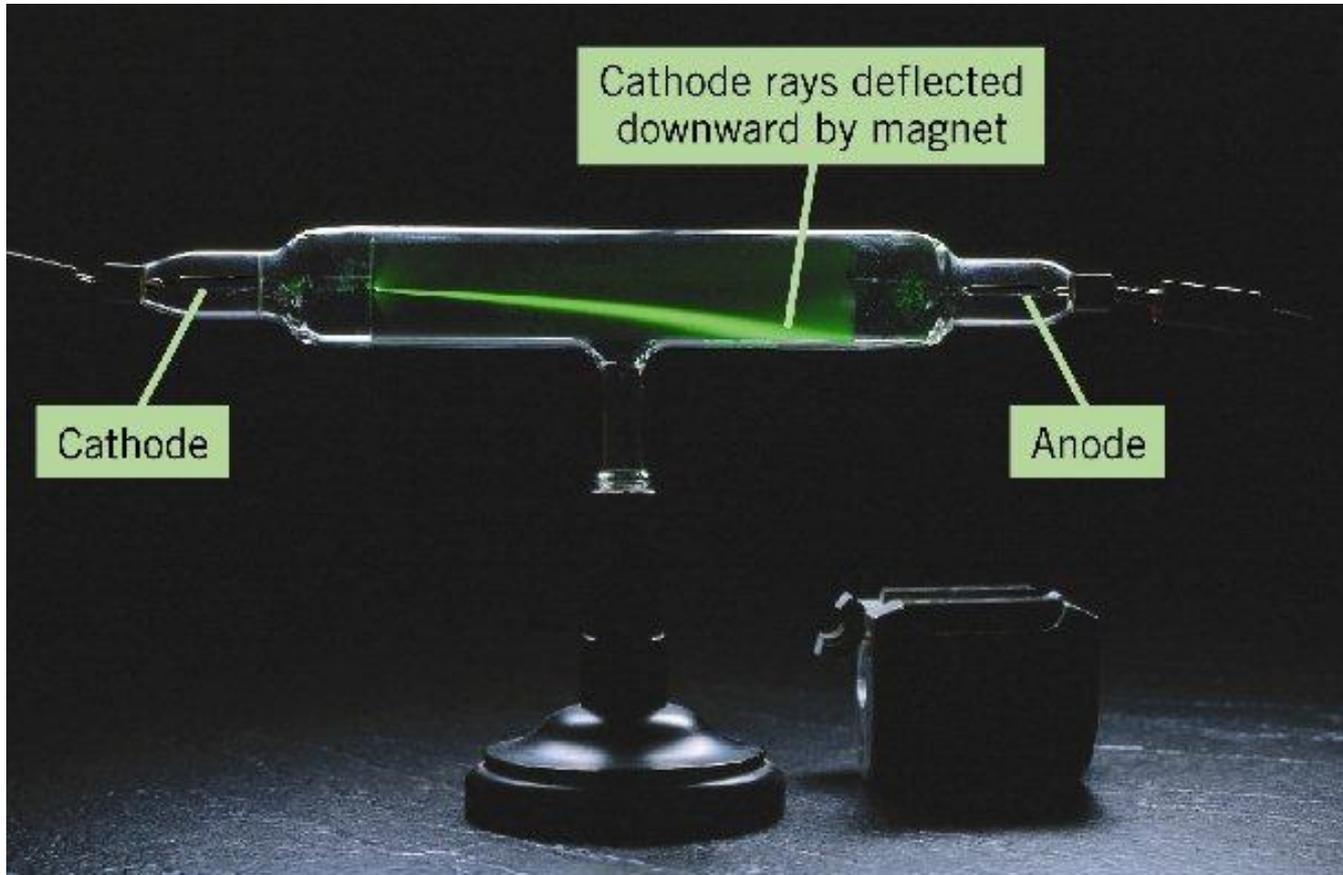
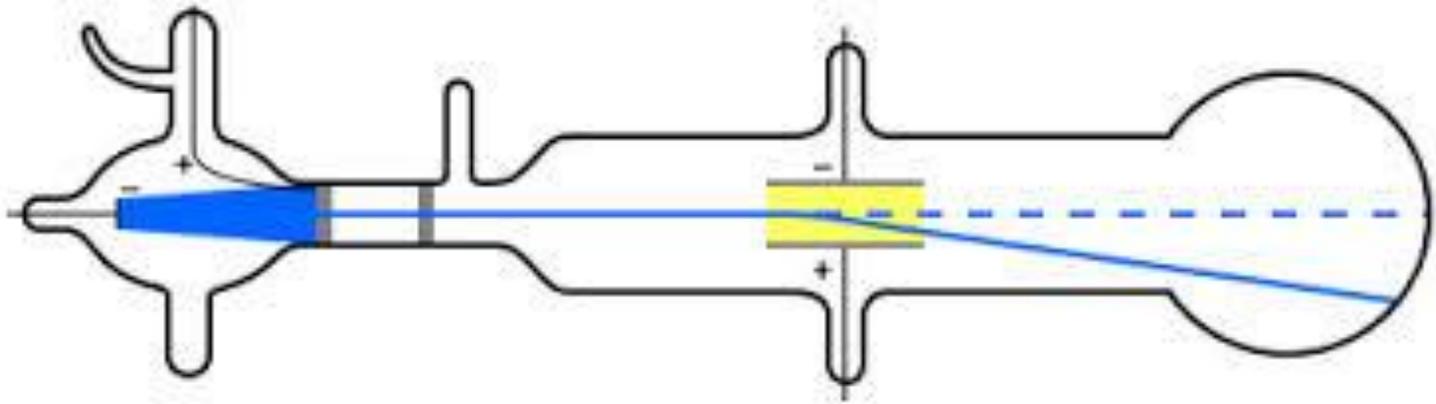


FIGURE 3. *Electron Experiment*



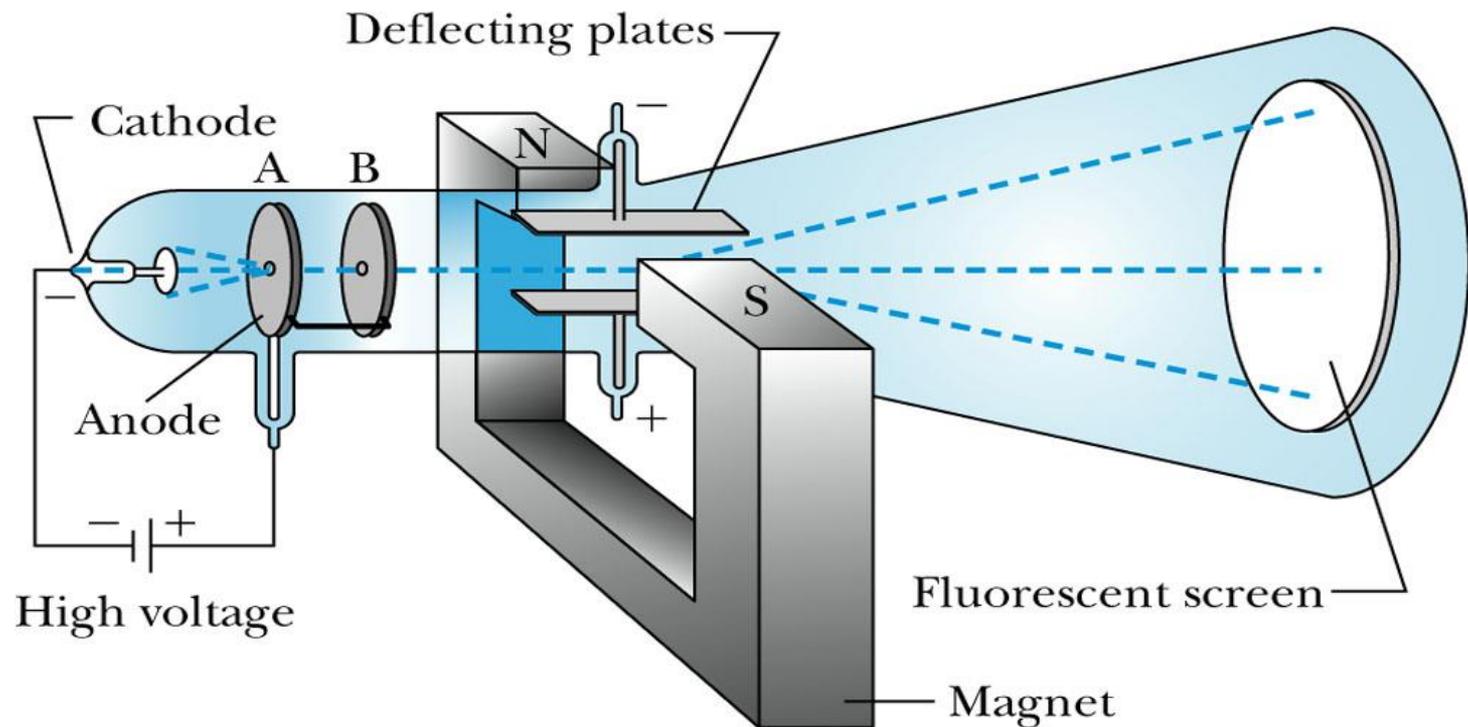




Joseph John Thomson (1856 – 1940) Inghilterra

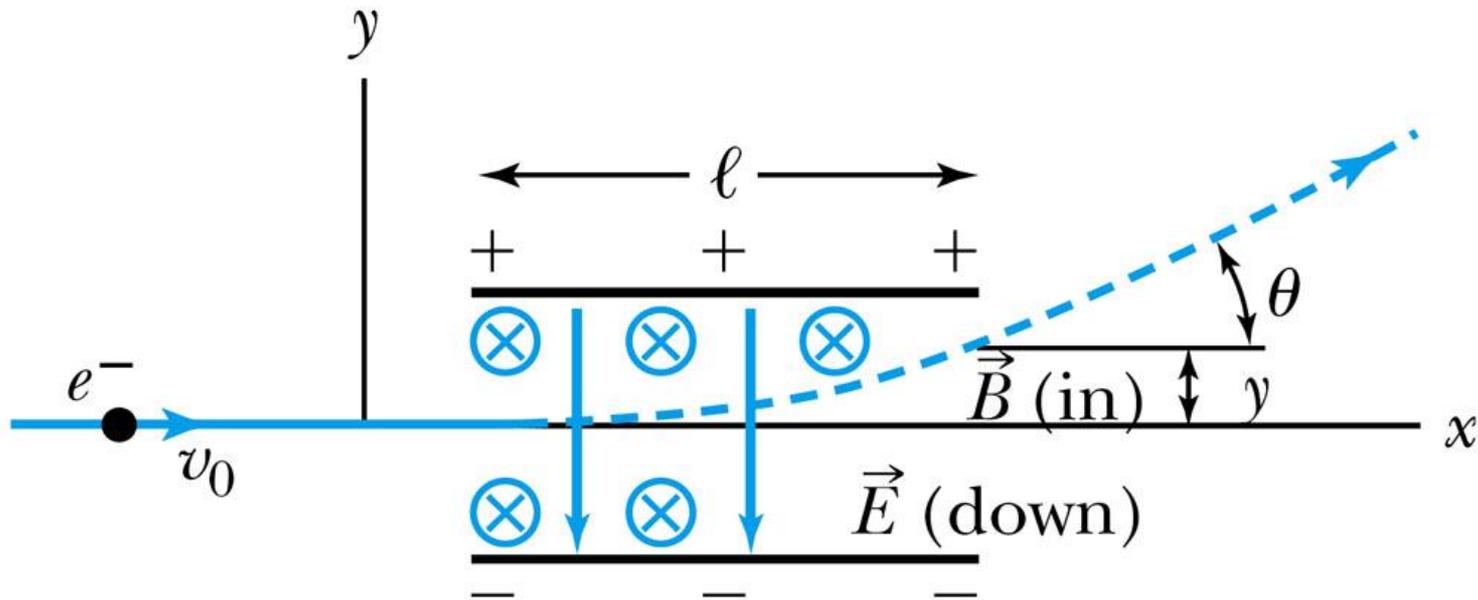
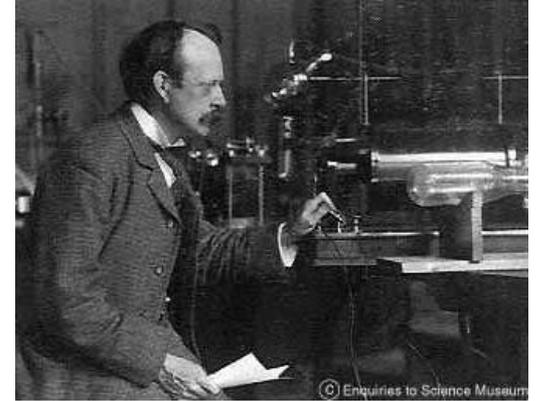
Thomson's Cathode-Ray Experiment

Thomson used an evacuated cathode-ray tube to show that the cathode rays were negatively charged particles (electrons) by deflecting them in electric and magnetic fields.



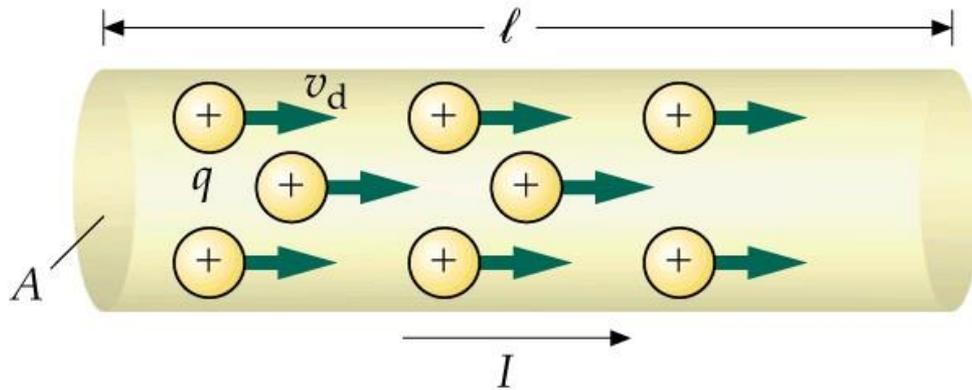
Thomson's Experiment: e/m

- Thomson's method of measuring the ratio of the electron's charge to mass was to send electrons through a region containing a magnetic field perpendicular to an electric field.



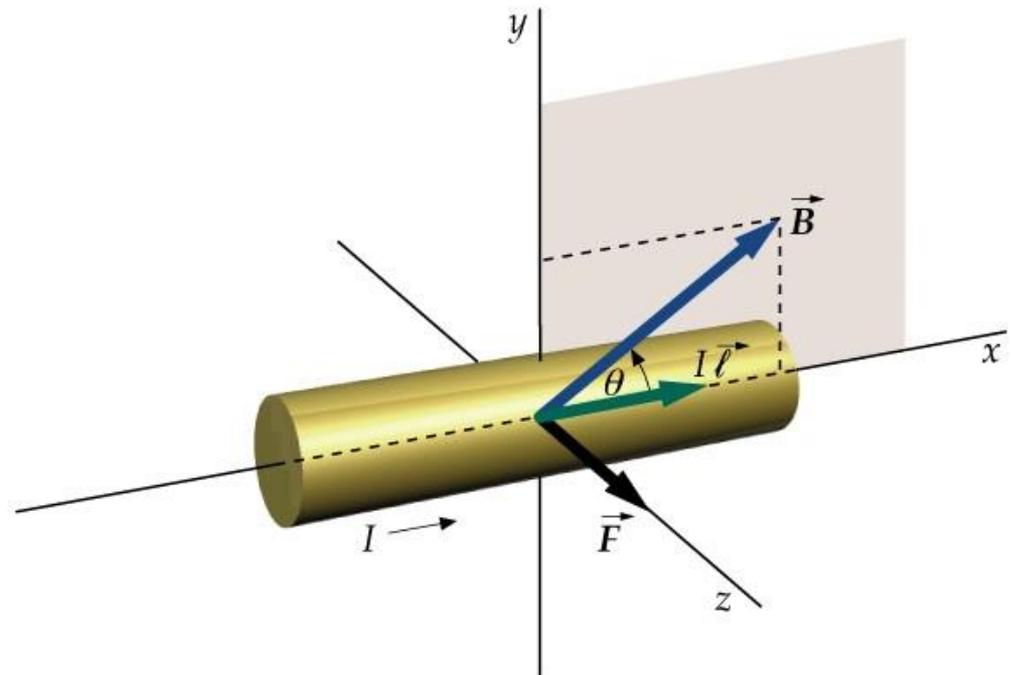
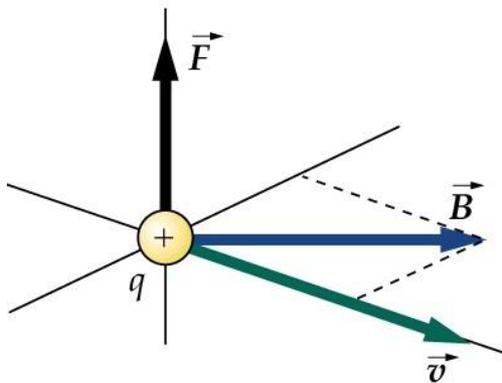


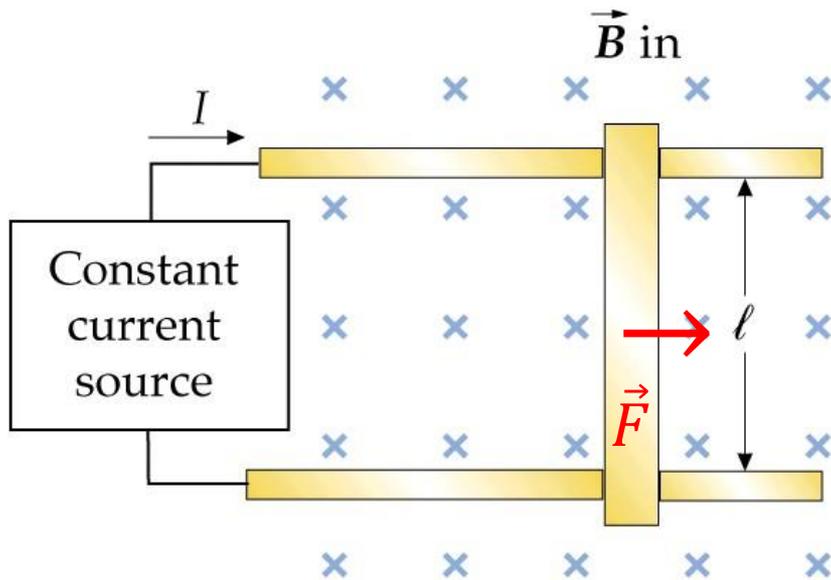
Força Magnética em fio com Corrente Elétrica



$$d\vec{F} = I d\vec{l} \times \vec{B}$$

elemento de corrente de comprimento dl

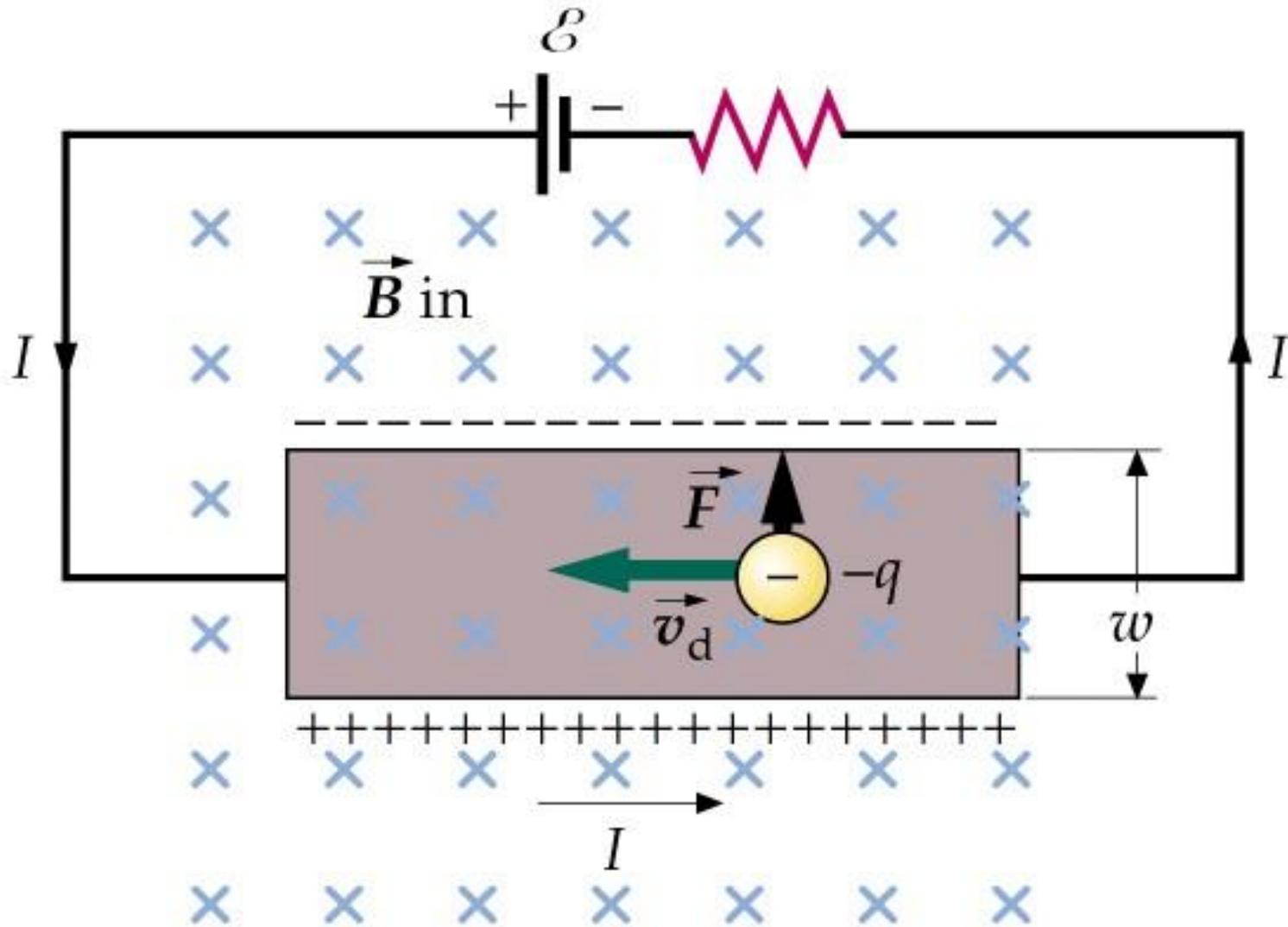


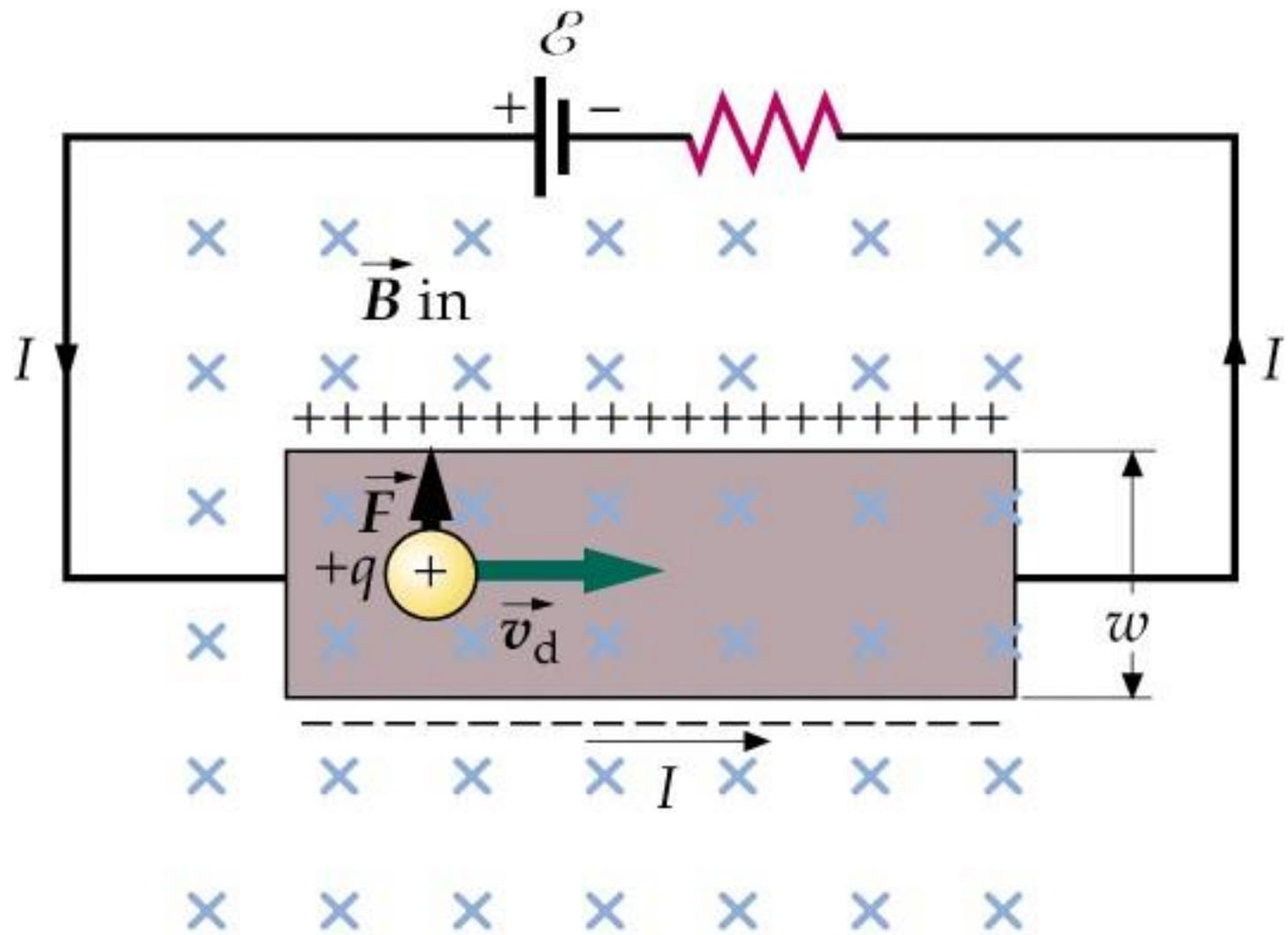


$$F = IlB$$

Obs: no vídeo o Prof. Eduardo usou uma fonte de tensão constante ao invés de uma fonte de corrente constante e o campo magnético aproximadamente perpendicular ao plano das barras metálicas, mas não era uniforme. Conseqüentemente, a expressão $F = i.L.B$, com corrente (i) e campo magnético (B) constantes é uma aproximação grosseira da demonstração. É claro que o objetivo foi demonstrar qualitativamente o fenômeno da Entretanto, a demonstração atende

Efeito Hall



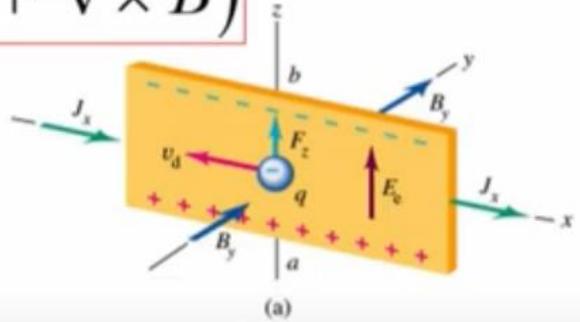
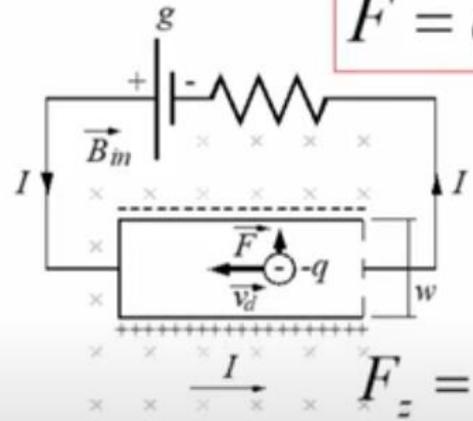




Medidas de Campos Magnéticos (Sensor de Efeito Hall)

Força eletromagnética (Força de Lorentz):

$$\vec{F} = q (\vec{E} + \vec{v} \times \vec{B})$$



$$F_z = -q (-E + v_d B)$$

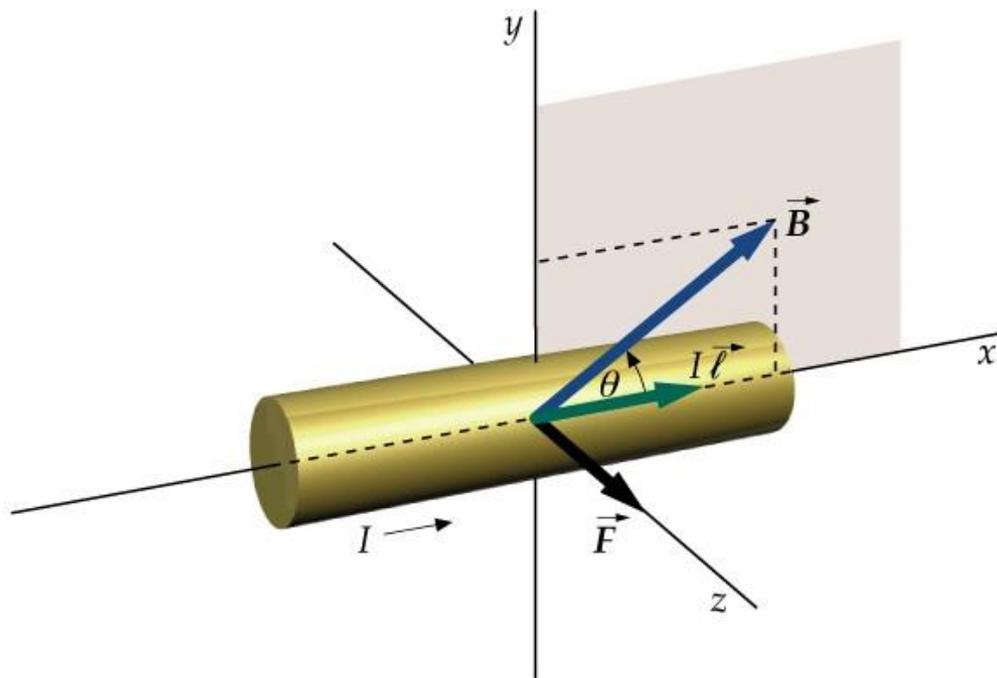
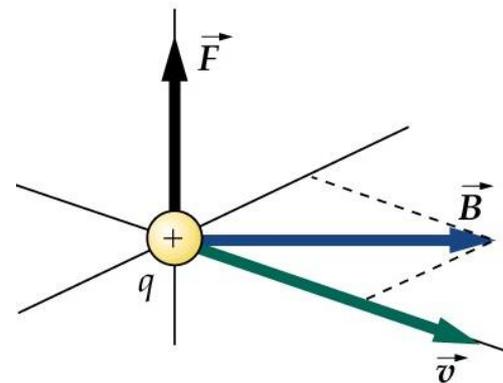
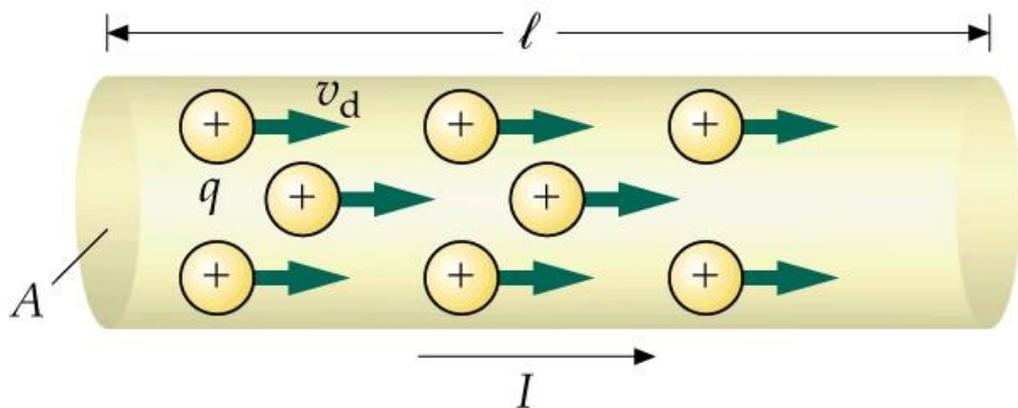
Qdo o equilíbrio é atingido:

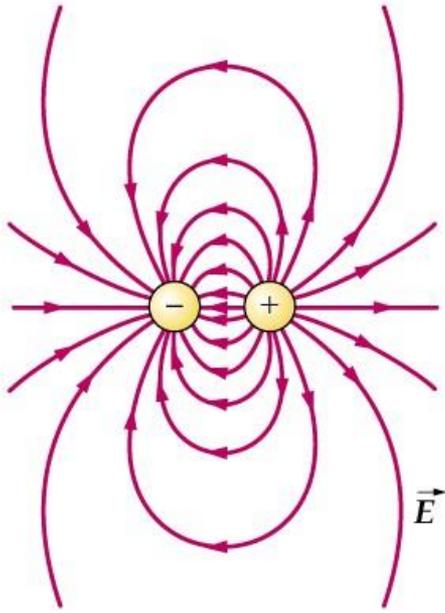
$$E = v_d B \rightarrow wE = wv_d B \rightarrow V_H = (wv_d) B$$



Video player controls: play, pause, volume, and progress bar showing 36:08 / 1:13:41.

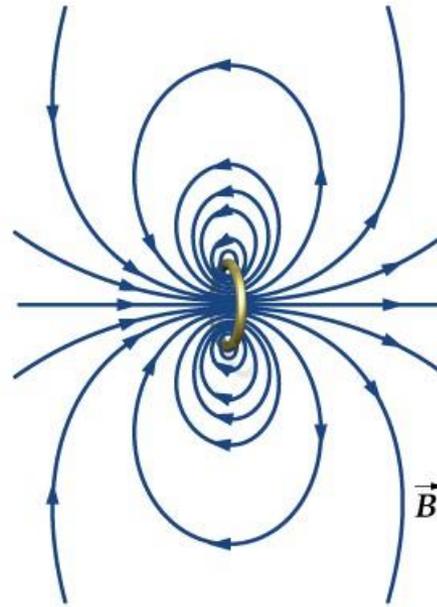
Força Magnética em fio com Corrente Elétrica





dipolo elétrico

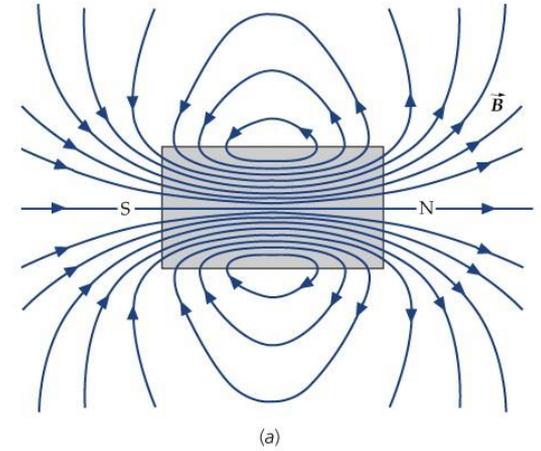
$$\vec{p} = q\vec{L}$$



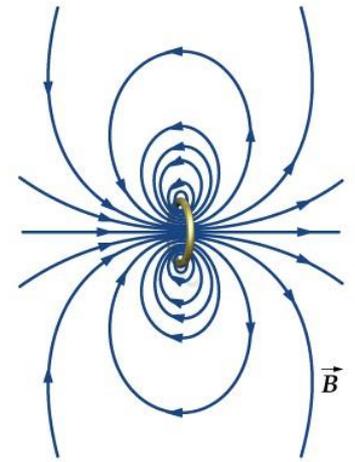
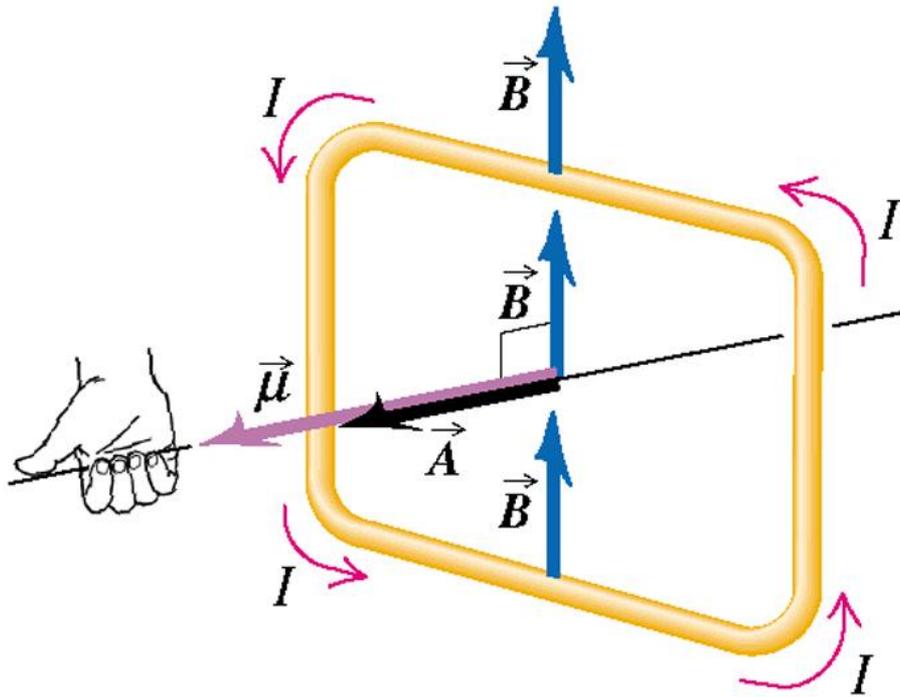
dipolo magnético

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

I = corrente
A = área do anel



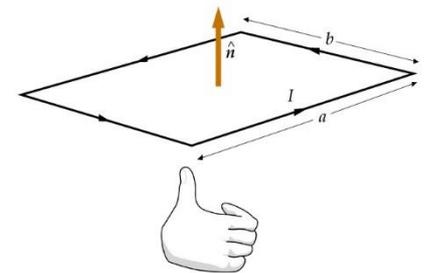
Momento Magnético ($\vec{\mu}$) de uma espira de corrente



$$\vec{\mu} = I \cdot \vec{A}$$

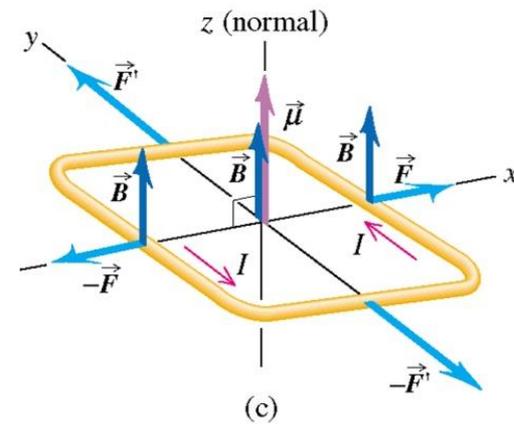
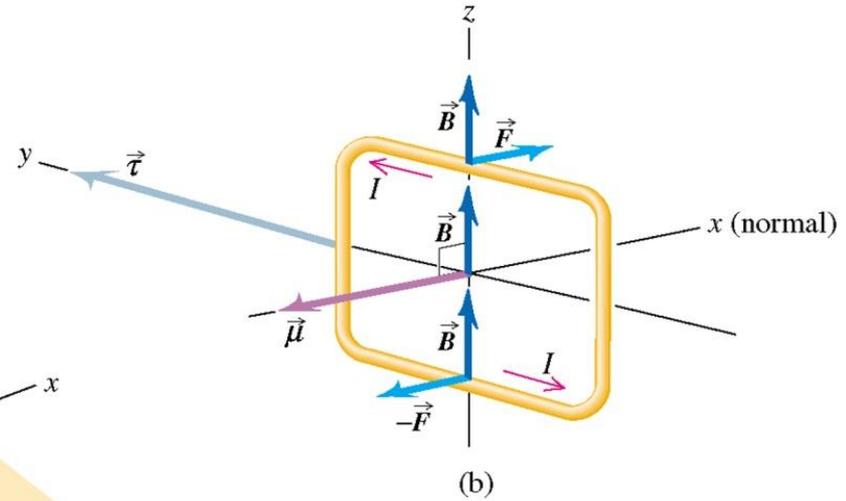
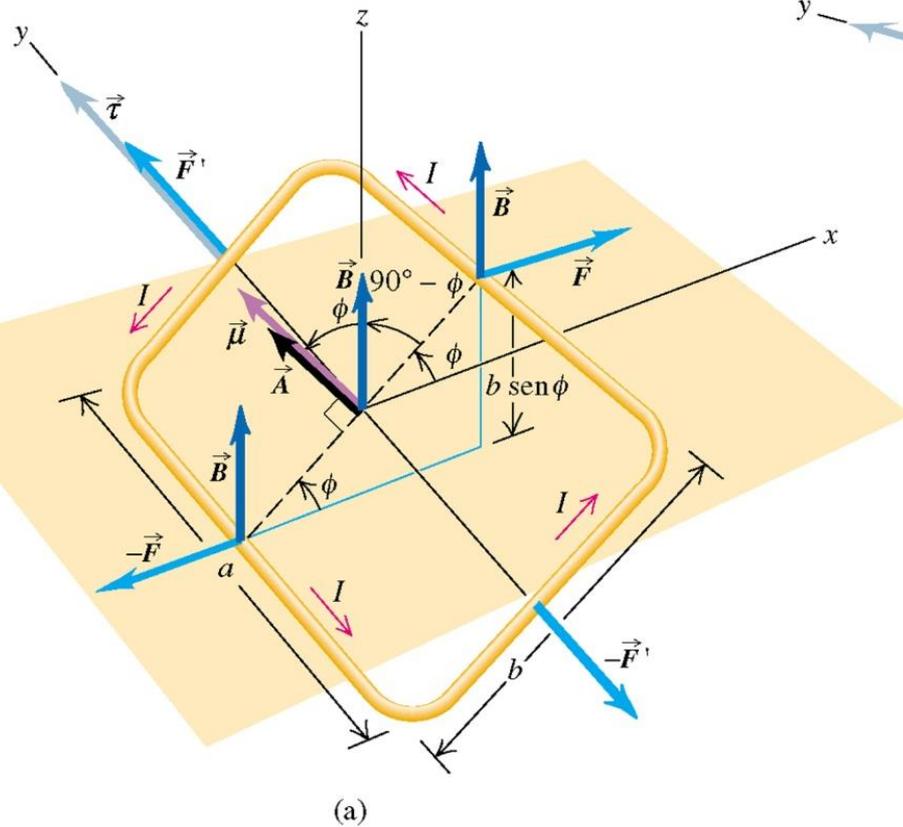
torque

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



Se a corrente (I) está no sentido dos dedos o $\vec{\mu}$ aponta na direção do polegar

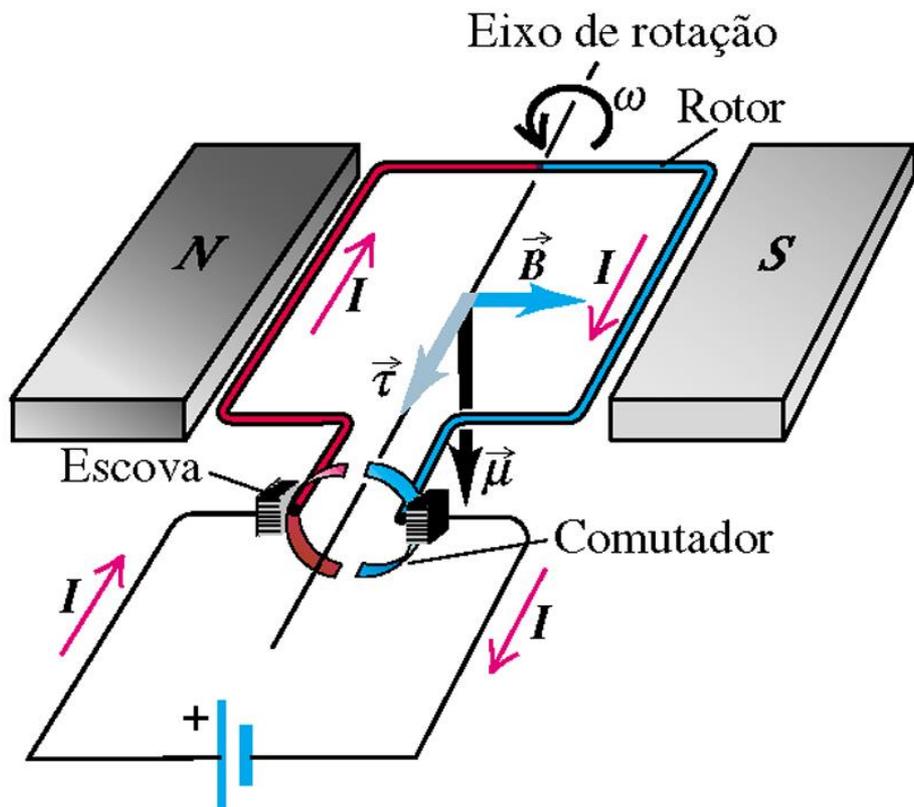
Torque em uma espira em um Campo Magnético Uniforme



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

$$U = -\vec{\mu} \cdot \vec{B}$$

Motor de Corrente contínua (“Direct Current”, DC)



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

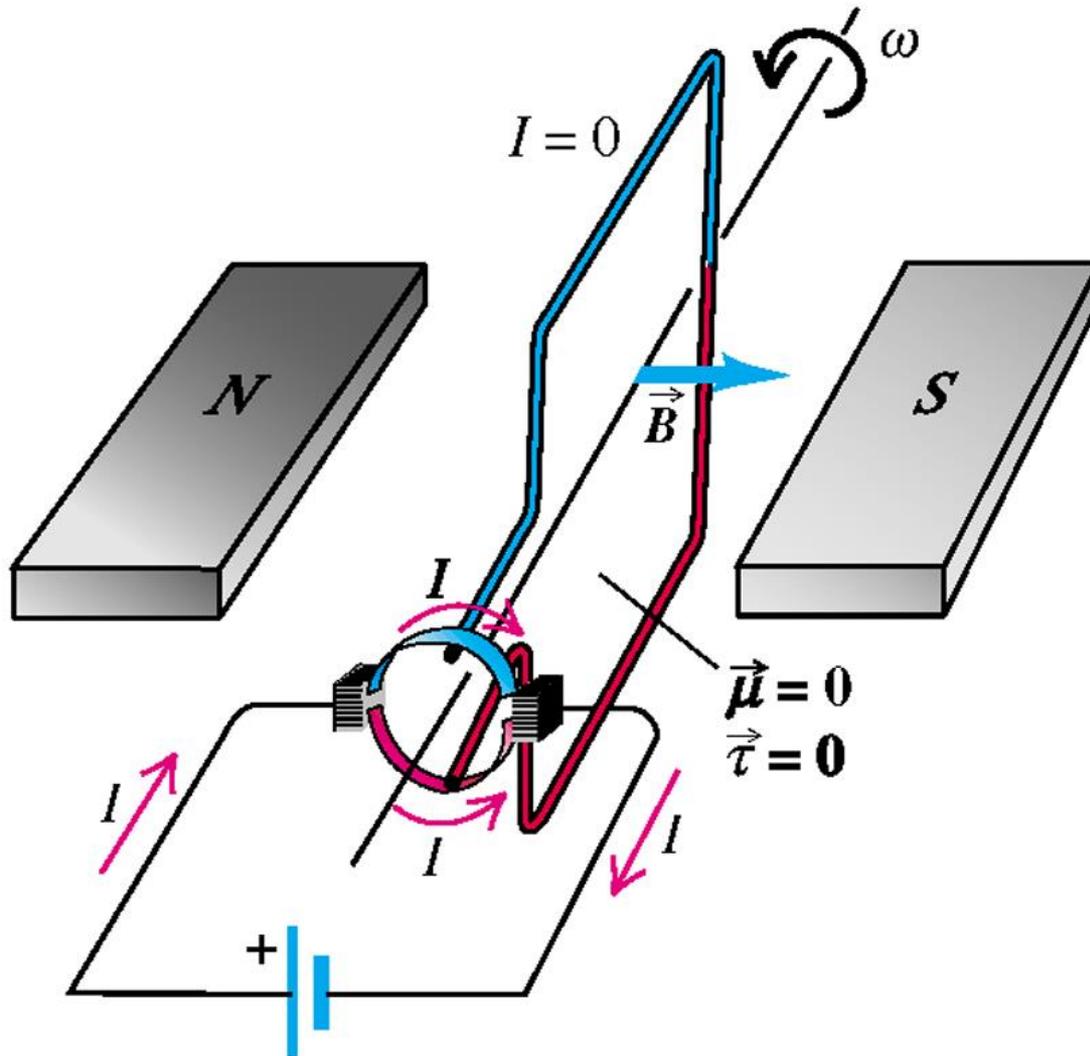
$$\tau = \mu \cdot B \cdot \text{sen}\theta$$

$$U = -\vec{\mu} \cdot \vec{B}$$

$$\theta = \pi/2$$

O torque na espira faz ela girar no sentido anti-horário buscando a posição de energia mínima ($\mu \parallel B$)

$$\theta = \pi/2$$



Cada escova está em contato com ambos segmentos do comutador
- Corrente nula \rightarrow torque zero mas $\omega \neq 0$

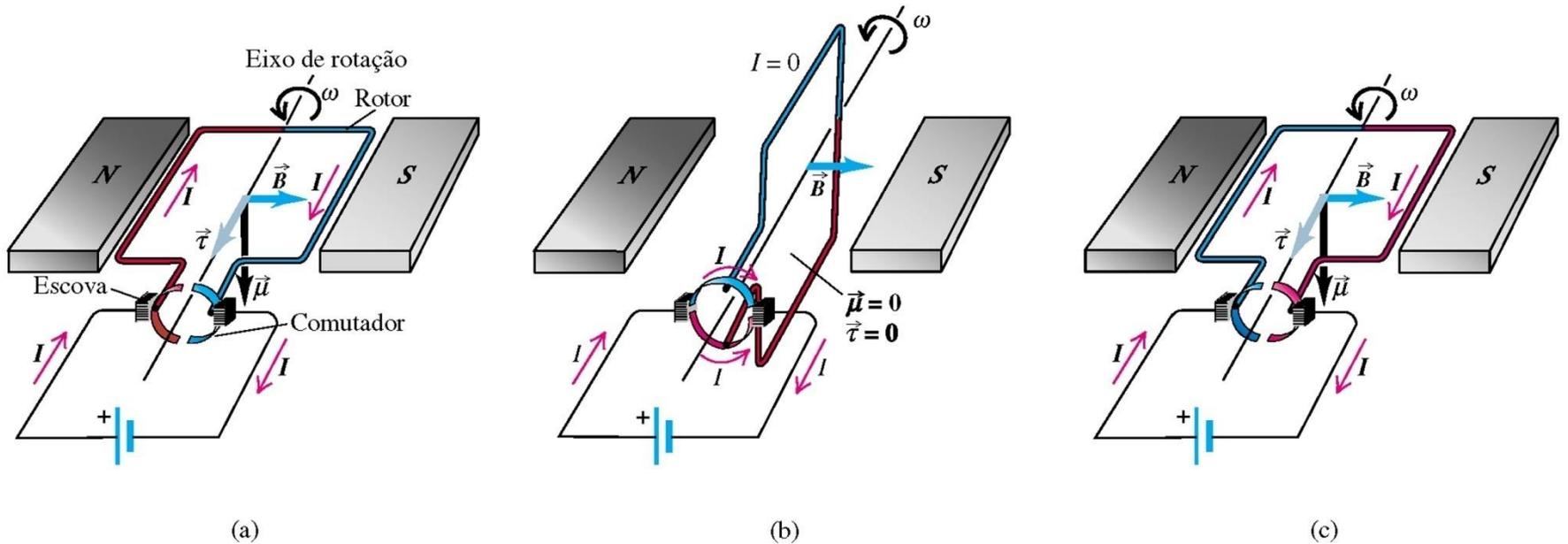


FIGURA 28.35 Diagrama esquemático de um motor de corrente contínua simples. O rotor é uma espira de fio que pode girar livremente; as extremidades do rotor são ligadas a dois condutores curvos que formam o comutador. Entre os dois segmentos do comutador, existe um material isolante. (a) As escovas são alinhadas sobre os segmentos do comutador e a corrente entra pelo lado esquerdo do rotor e sai pelo lado direito. O torque magnético faz o rotor girar no sentido anti-horário. (b) O rotor girou de 90° . Cada escova está em contato com ambos os segmentos do comutador, de modo que a corrente passa por baixo e a corrente do rotor se interrompe. (c) Depois que o rotor ultrapassou a posição indicada em (b), a corrente volta a fluir através dos lados opostos dos comutadores e atravessa o rotor no mesmo sentido que o indicado em (a). Logo, o torque magnético continua atuando no mesmo sentido que o indicado em (a).

