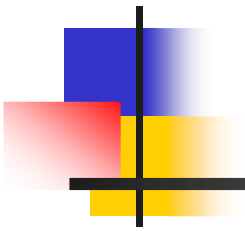


Magnetostàtica

La força de Lorentz

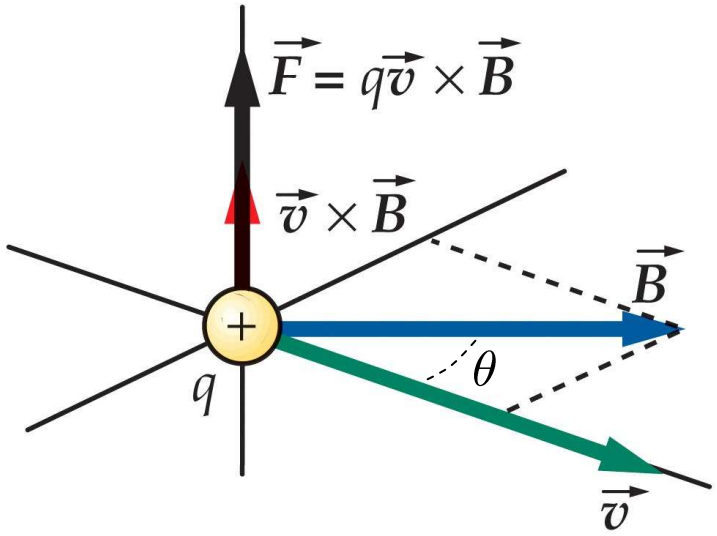
Camp magnètic $\vec{B}(\vec{r})$

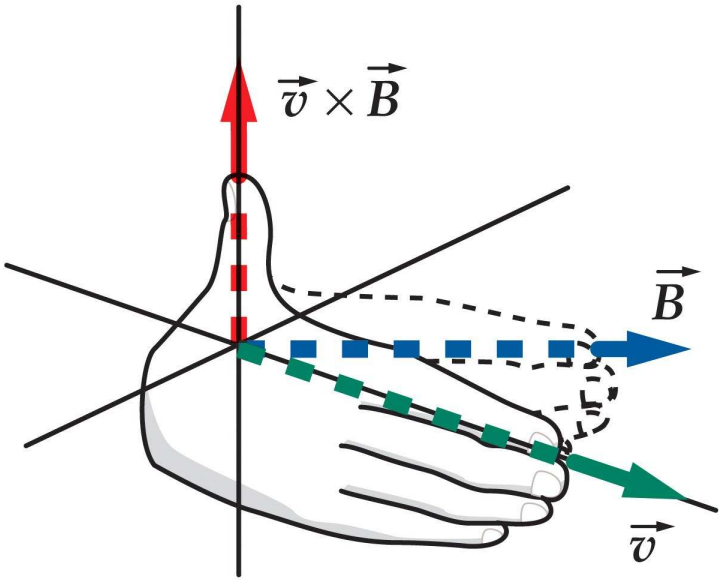
Una càrrega en moviment dins un camp magnètic experimenta una força

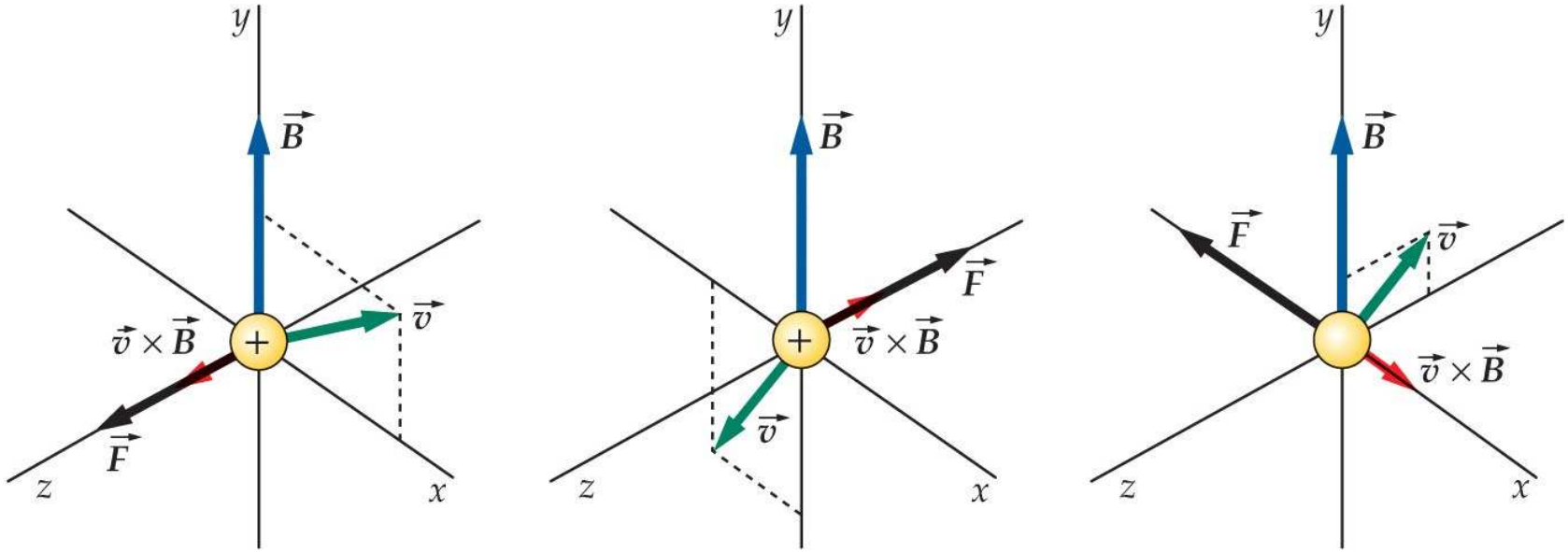
$$\vec{F} = q\,\vec{v} \times \vec{B}$$

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

$$F = qvB\sin\theta$$







Unitat

$$[B] = \frac{[F]}{[qv]} = \frac{\mathrm{N}}{\mathrm{C\,m}} = \mathrm{T} \quad \text{tesla}$$

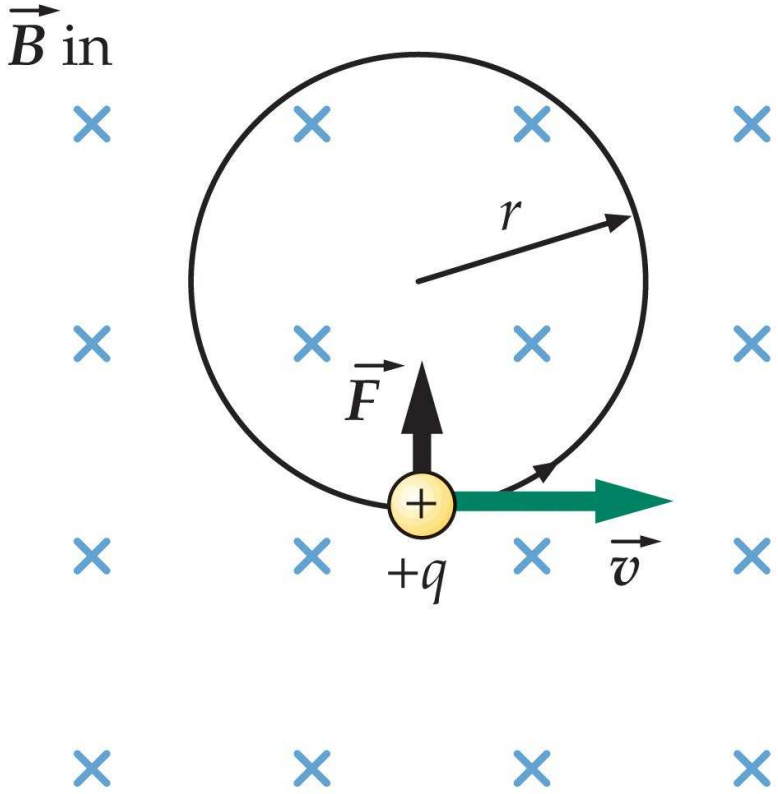
A vegades

weber $\mathrm{Wb} = \mathrm{T\,m^2}$ (flux de camp magnètic)

$\mathrm{T} = 10^4 \mathrm{G}$ gauss

camps de laboratori $B \lesssim 1\mathrm{T}$

Moviment d'una càrrega puntual



Moviment circular uniforme
acceleració centrípeta

$$\vec{F}_{\text{cent}} = q\,\vec{v} \times \vec{B}$$

$$m\frac{v^2}{r} = qvB \qquad \boxed{r = \frac{mv}{qB}}$$

velocitat angular constant

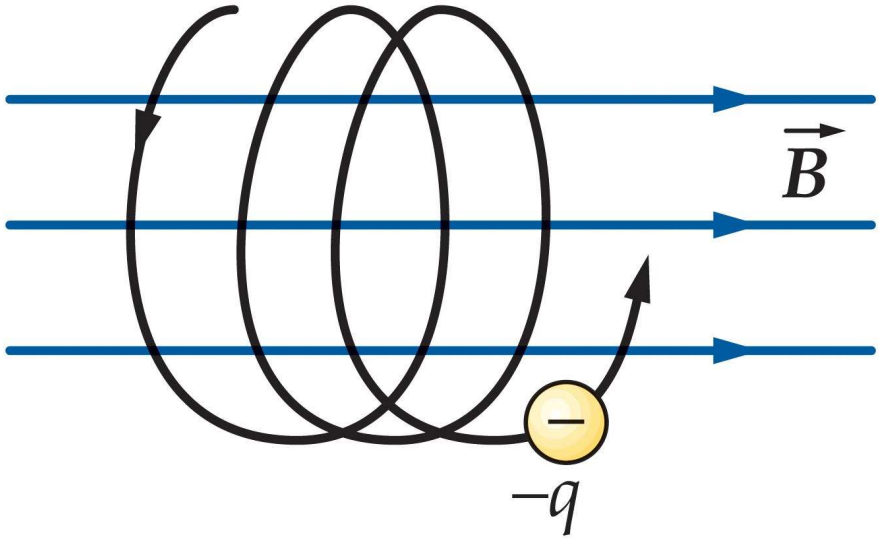
$$\omega \equiv \frac{v}{r} = \frac{qB}{m}$$

freqüència i periode

$$\omega = 2\pi f = \frac{2\pi}{T}$$

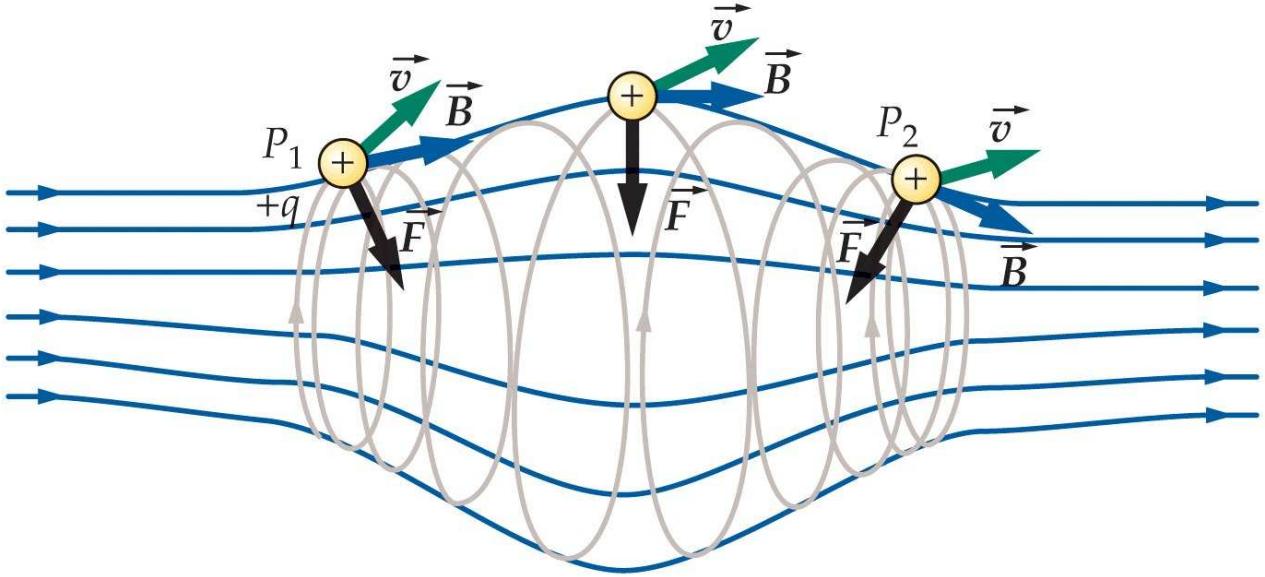
Freqüència f i freqüència angular ω

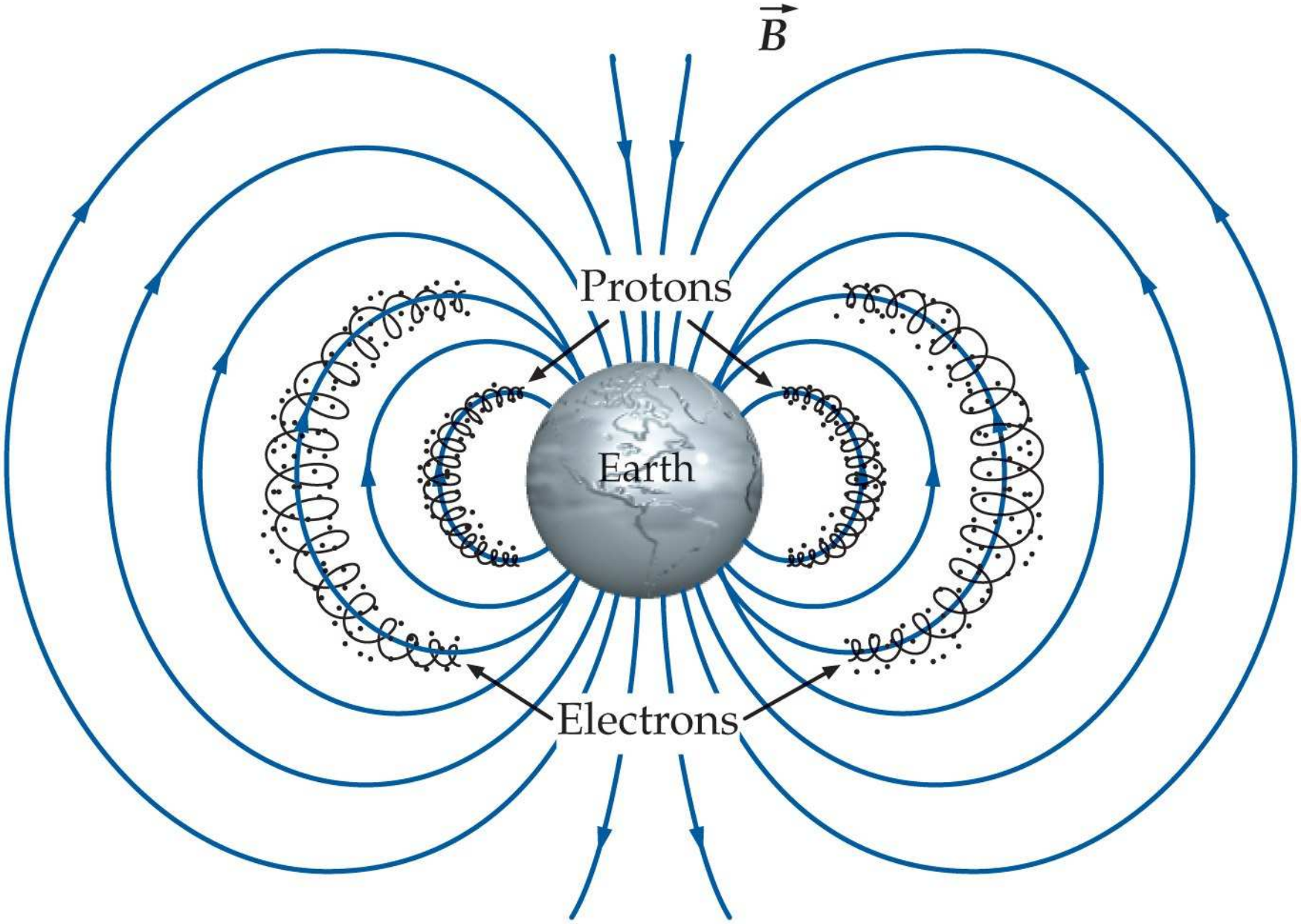
$$\omega_c = \frac{qB}{m}$$ *freqüència de ciclotró*



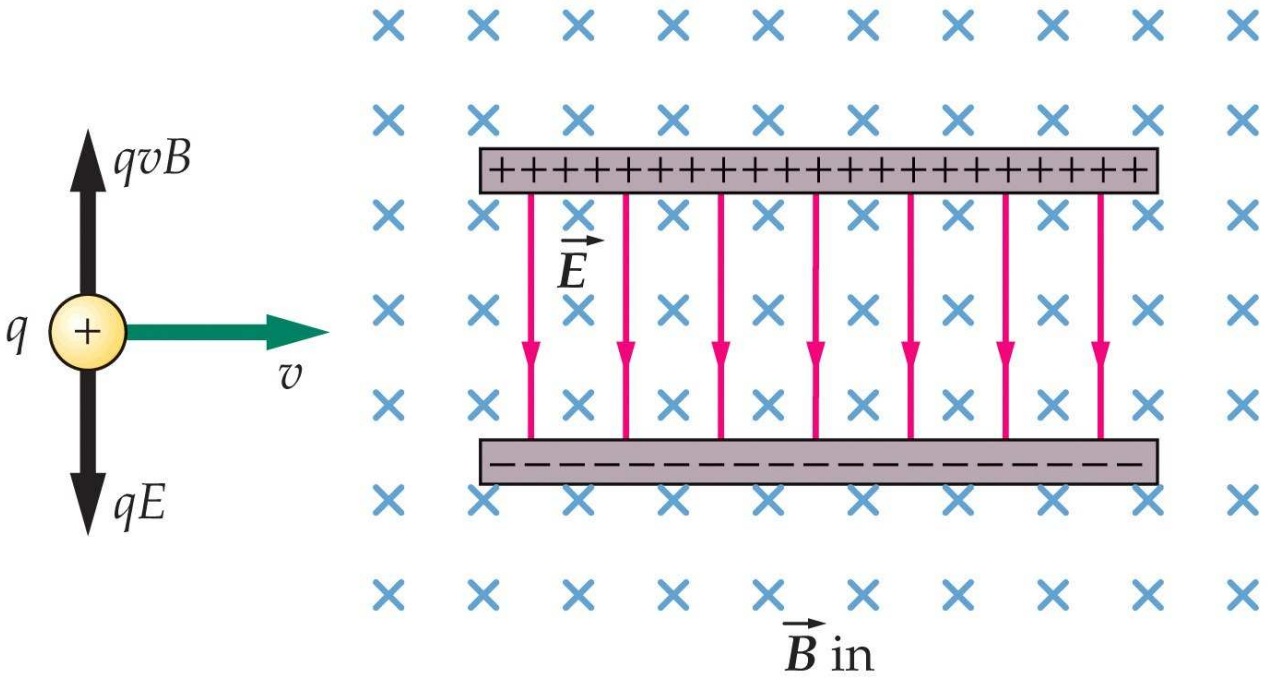
$$\vec{v} = v_{\parallel}\hat{u}_{\parallel} + v_{\perp}\hat{u}_{\perp}$$

$$r = \frac{mv_{\perp}}{qB}$$

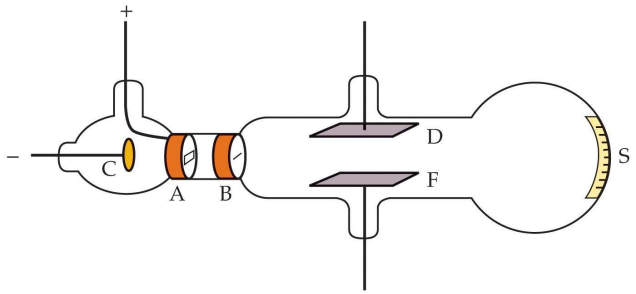



$\vec{B}$
Protons
Earth
Electrons

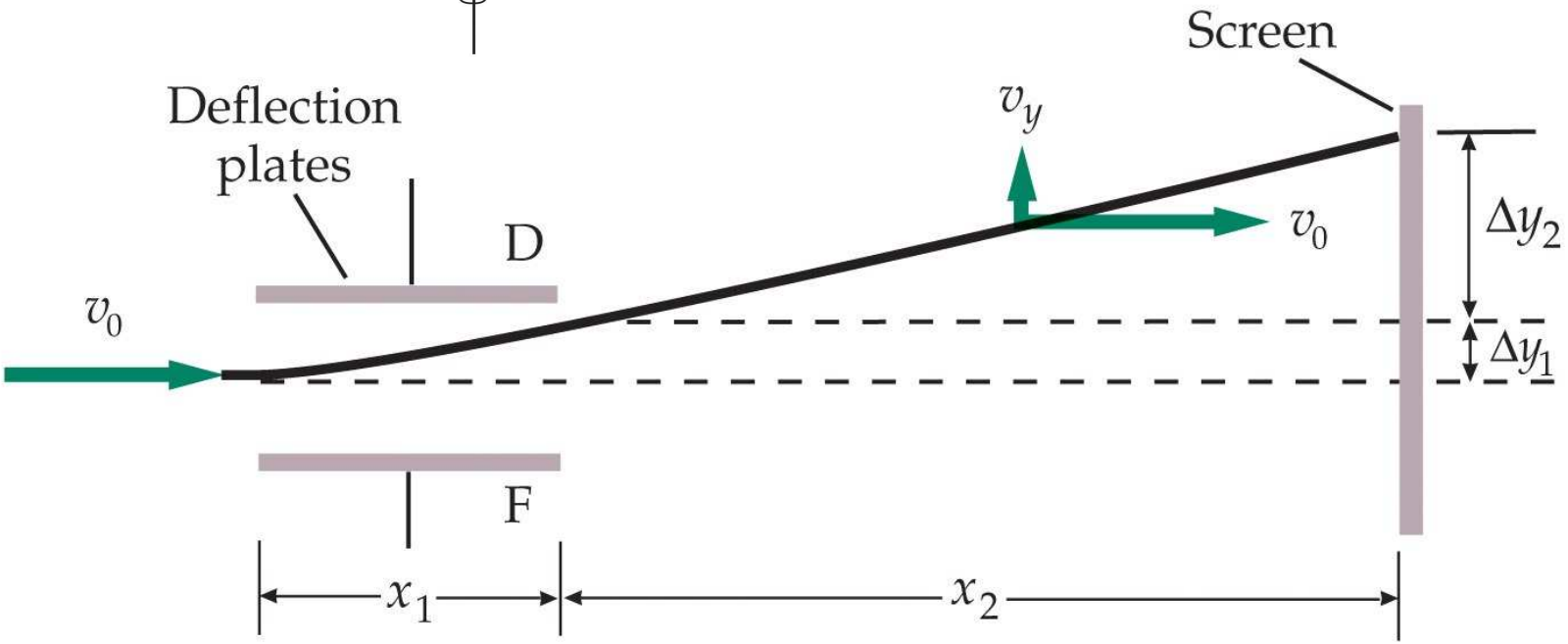
$$\vec{F} = q\left(\vec{E} + \vec{v} \times \vec{B}\right)$$



L'experiment de Thomson



Tub de rajos catòdics

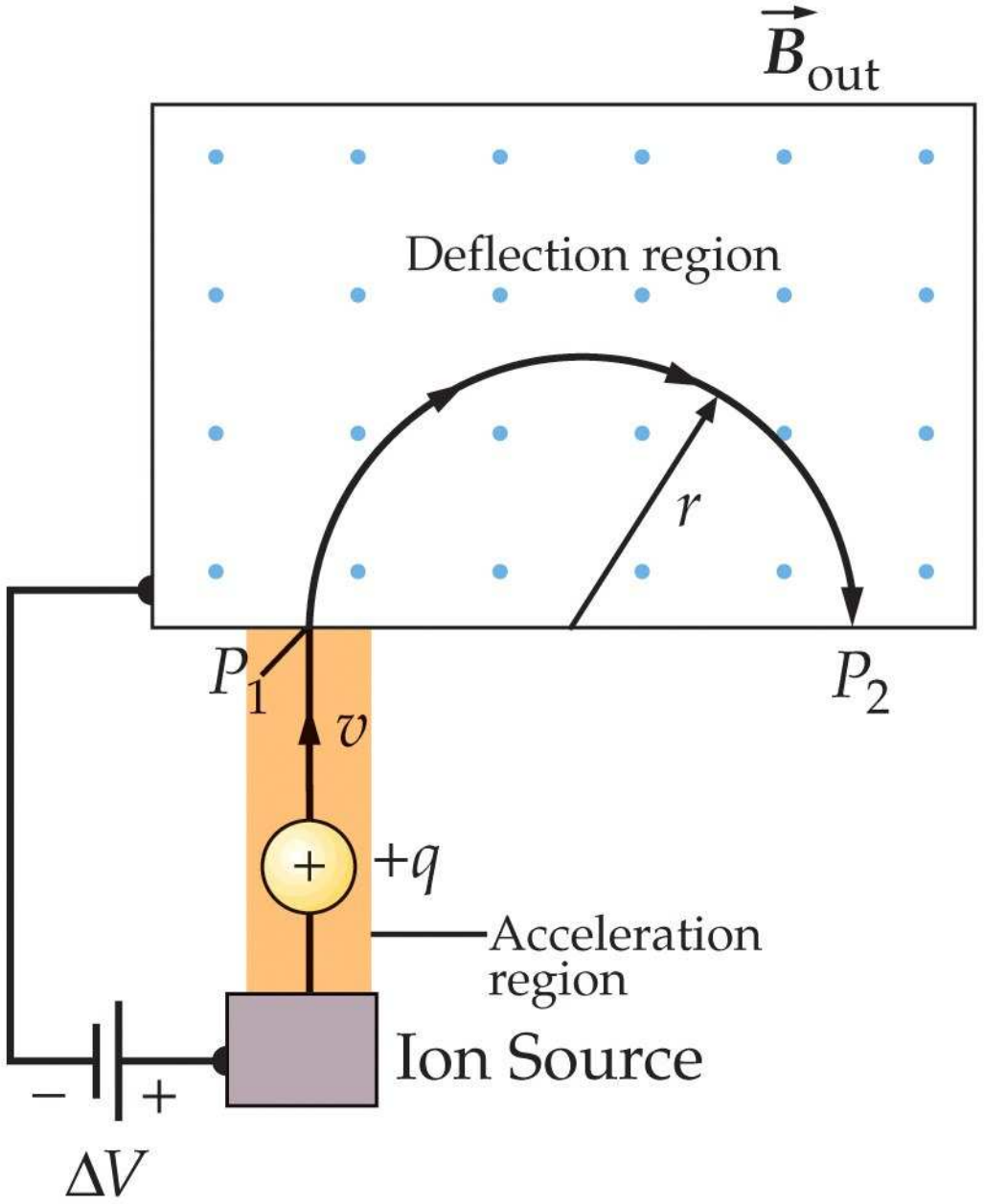


$$\Delta y_1 = \frac{1}{2}\left(\frac{qE}{m}\right)\left(\frac{x_1}{v_0}\right)^2$$

Sense deflexió $\dfrac{qE}{m} = qv_0B$

$$\frac{q}{m} \approx 1.76 \times 10^{11}\ \frac{\mathrm{C}}{\mathrm{kg}}$$

Espectròmetre de masses

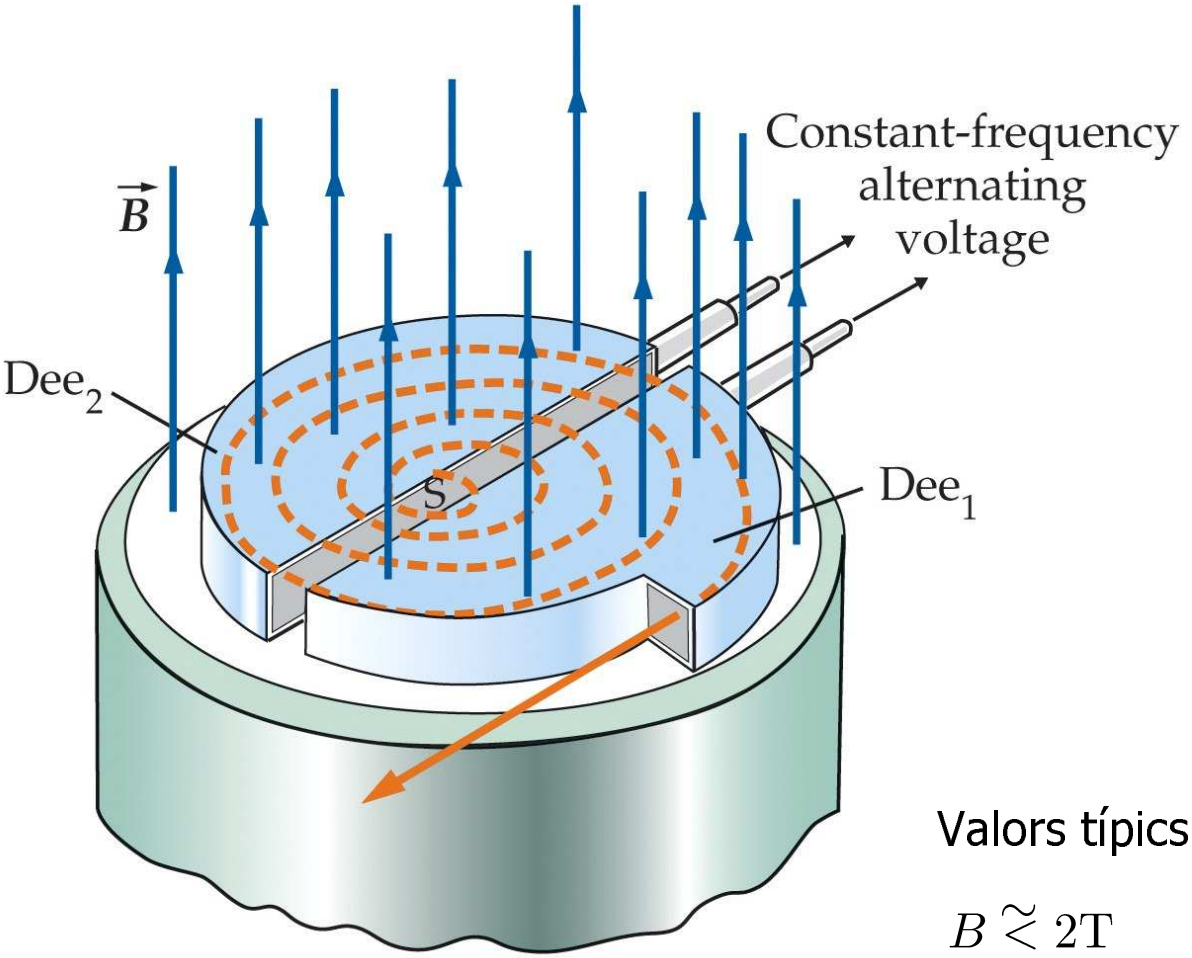


$$\frac{1}{2}mv^2 = q|\Delta V|$$

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

$$\frac{m}{q} = \frac{B^2r^2}{2|\Delta V|}$$

El ciclotró



$$V = V_0 \cos \omega_p t$$

$$\omega_p = \omega_c \quad (\omega_p = n\omega_c)$$

$$v_{\max} = \omega_c R_{\max} = \frac{qB}{m} R_{\max}$$

$$E_{\max} = \frac{1}{2} m v_{\max}^2$$

$$= \frac{1}{2} \frac{q^2 B^2}{m} R_{\max}^2$$

Valors típics

$B \lesssim 2\text{T}$

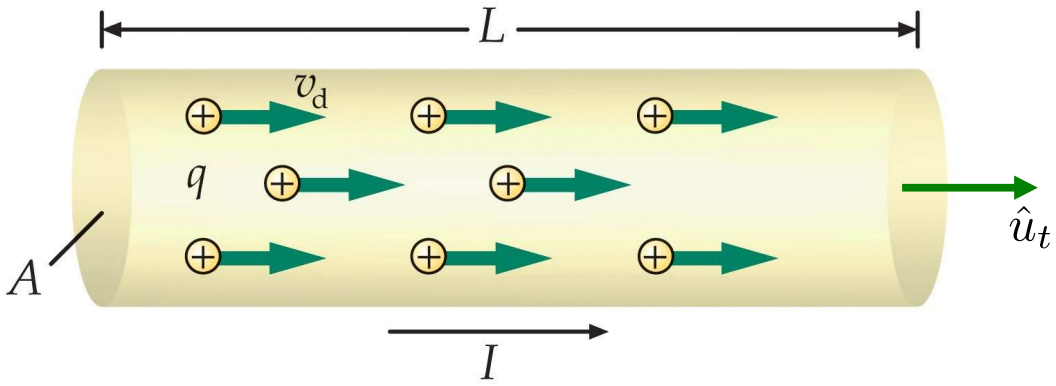
$R \approx 30\text{cm}$

protons

$E_{\max} \approx 2\text{MeV}$

$(1\text{MeV} = 10^6\text{eV} = 10^6\, 1.6\, 10^{-19}\text{J})$

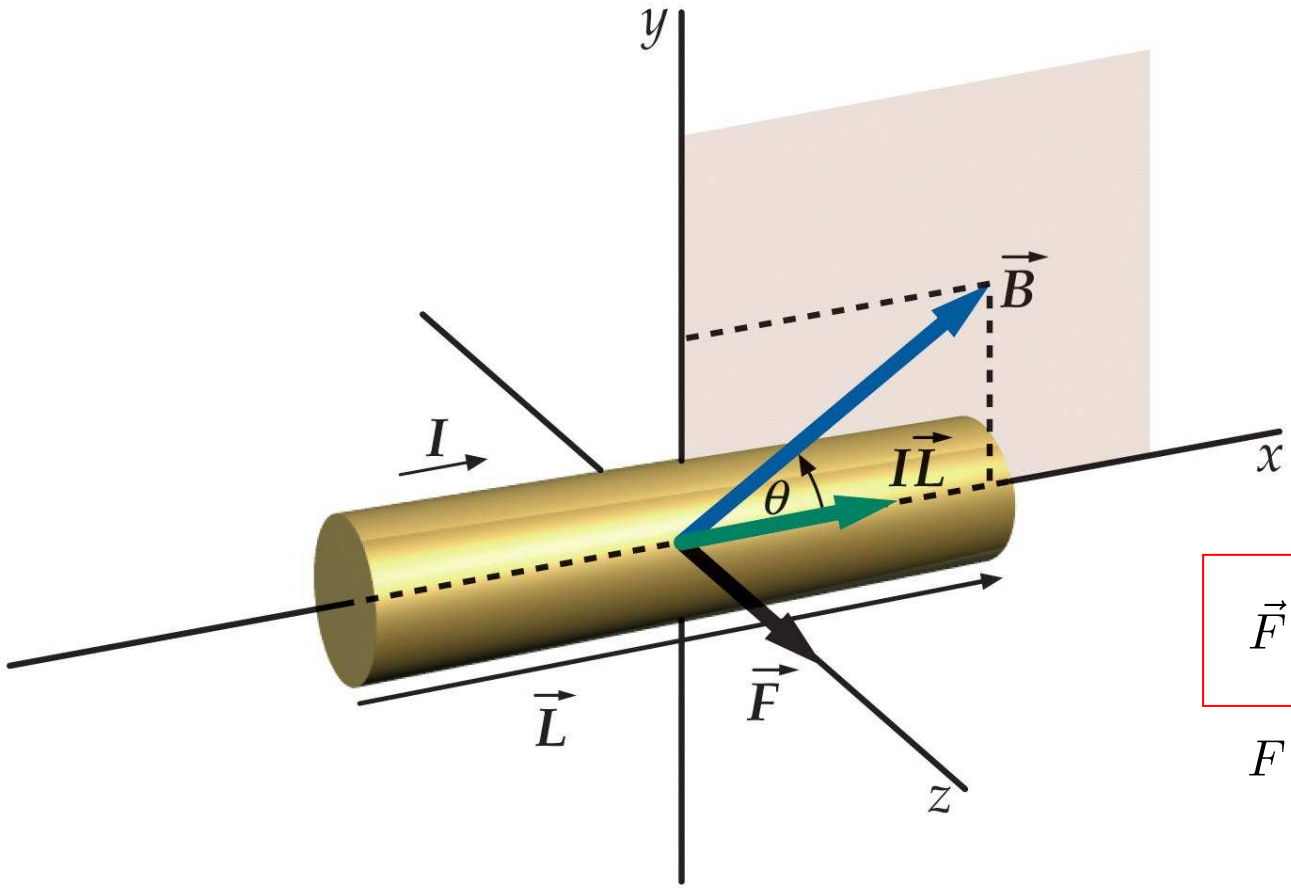
Força magnètica sobre un corrent



$$\Delta\vec{F} = (n\Delta V)q\vec{v}_d \times \vec{B}$$

$$\Delta\vec{F} = \vec{j} \times \vec{B}\ \Delta V$$

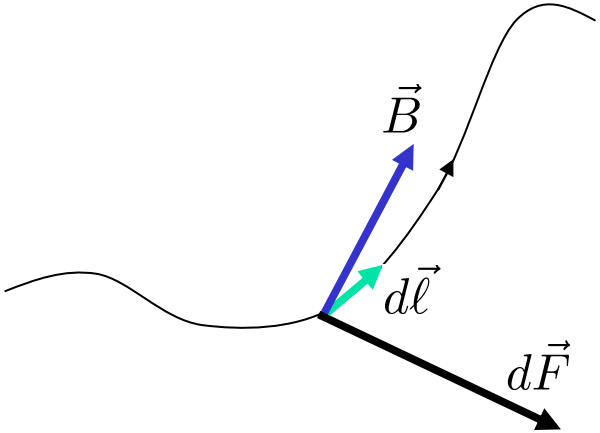
$$\frac{\Delta\vec{F}}{\Delta L} = \vec{j} \times \vec{B}\ A = I\hat{u}_t \times \vec{B}$$



$$\vec{F} = I\vec{L} \times \vec{B}$$

$$F = ILB\sin\theta$$

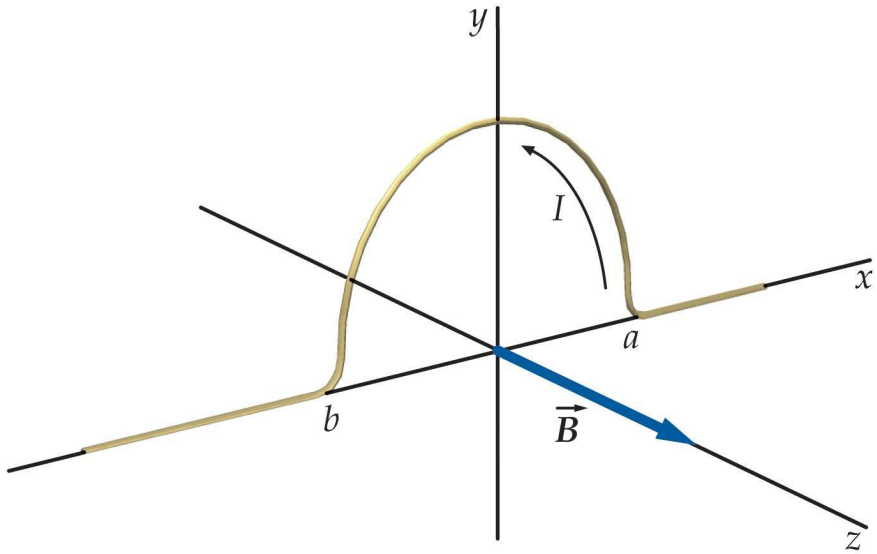
$$d\vec{F} = Id\vec{\ell} \times \vec{B} \qquad 26\text{-}5$$



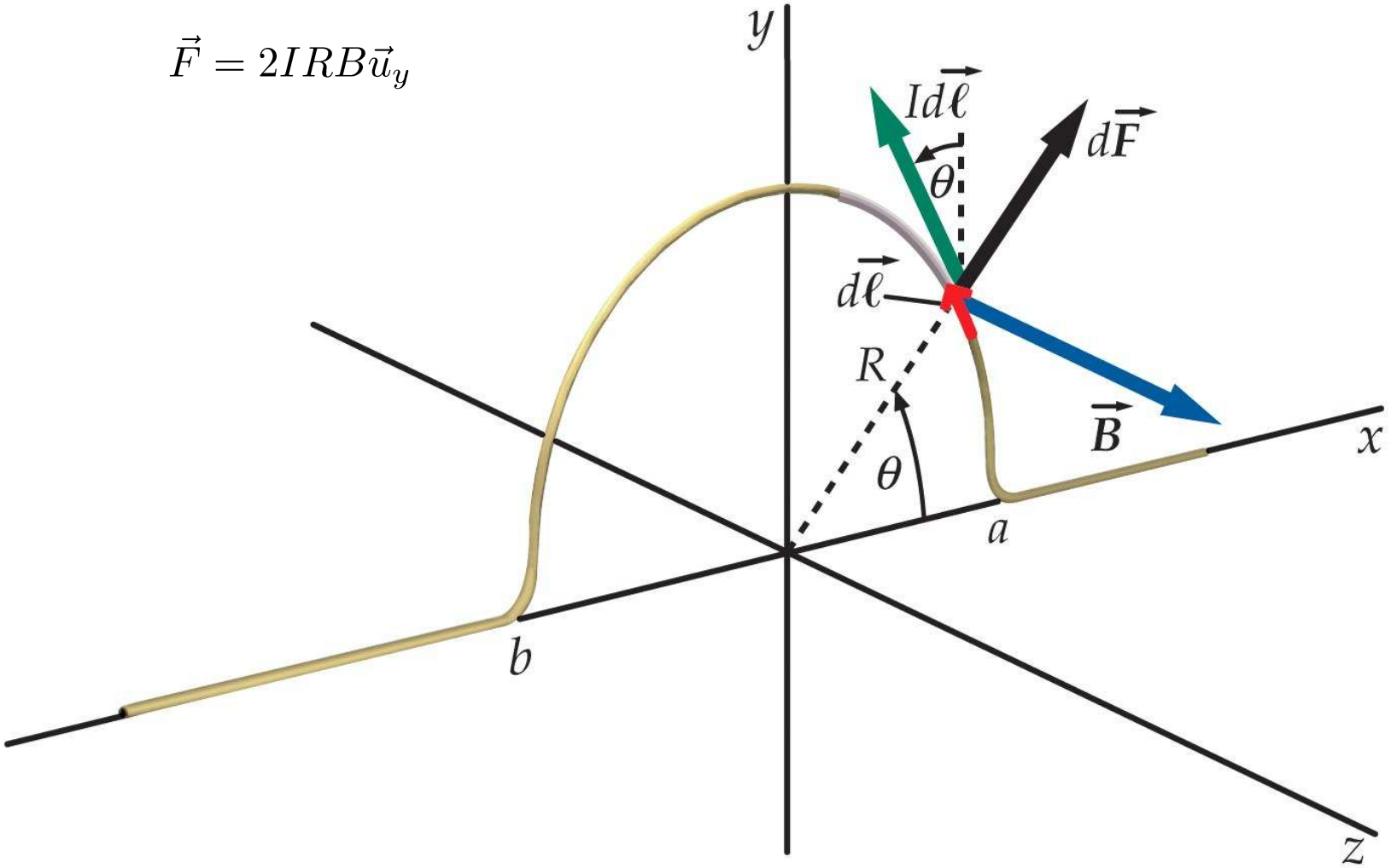
MAGNETIC FORCE ON A CURRENT ELEMENT

$$\vec{F} = \int d\vec{F} = I \int d\vec{\ell} \times \vec{B}$$

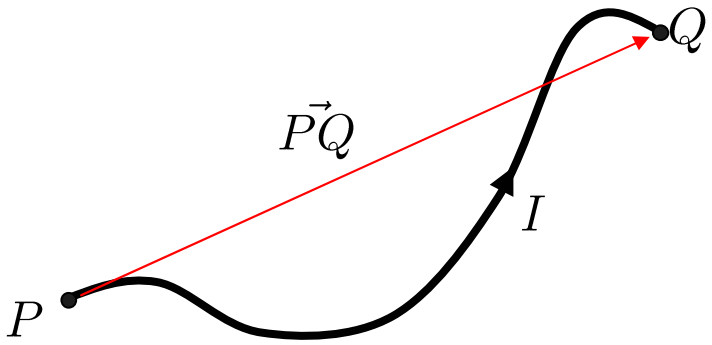
Exemple:



$$\vec{F} = 2IRB\vec{u}_y$$



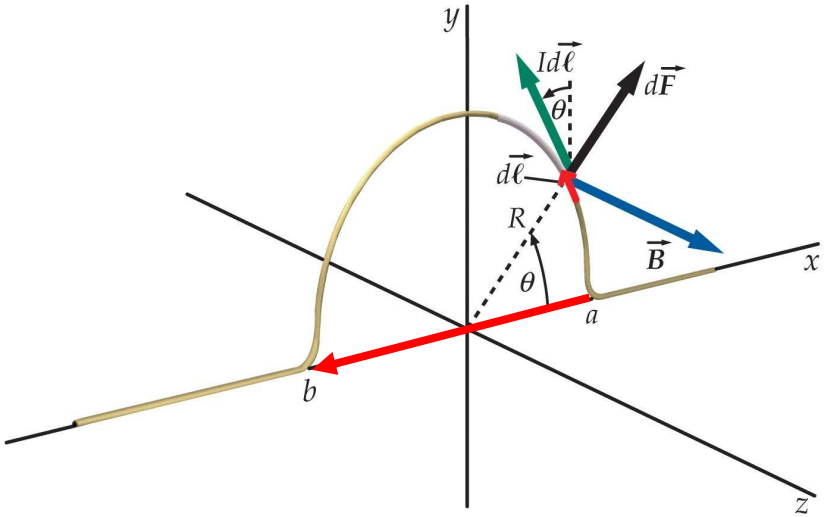
Camp uniforme i fil arbitrari



$$\vec{F} = \int d\vec{F} = I \int d\vec{\ell} \times \vec{B}$$

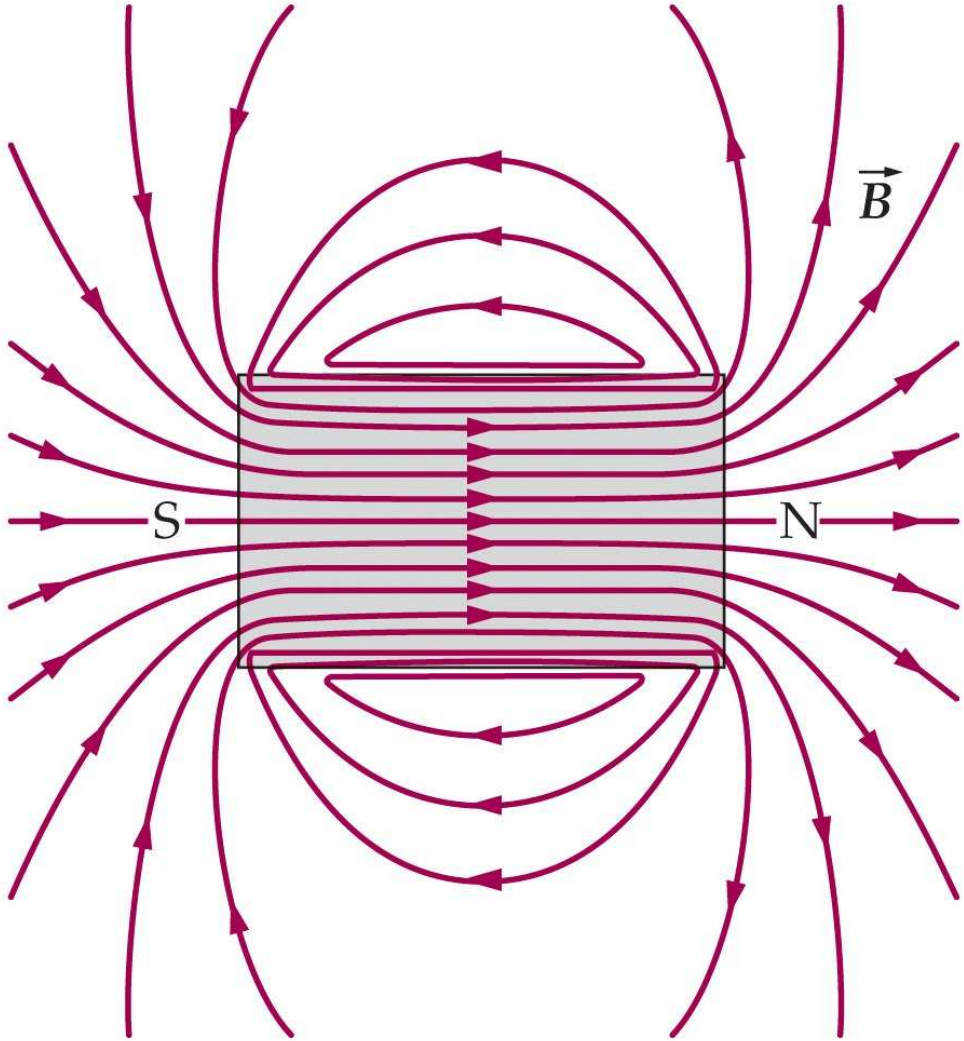
$$\int_P^Q d\vec{\ell} = \vec{PQ}$$

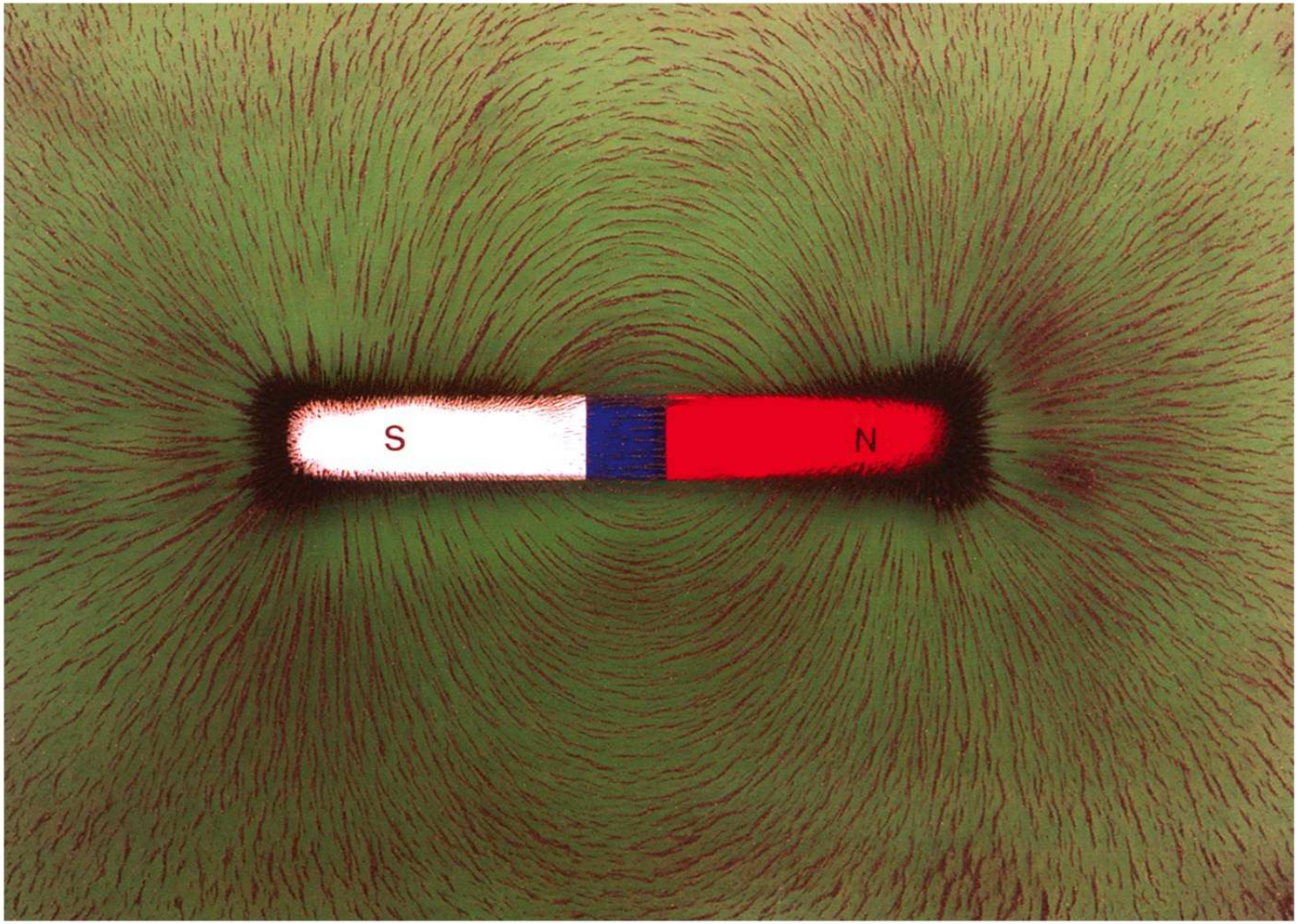
$$\vec{F} = I\,\vec{PQ} \times \vec{B}$$



$$\vec{F} = 2IRB\vec{u}_y$$

Les línies de camp magnètic

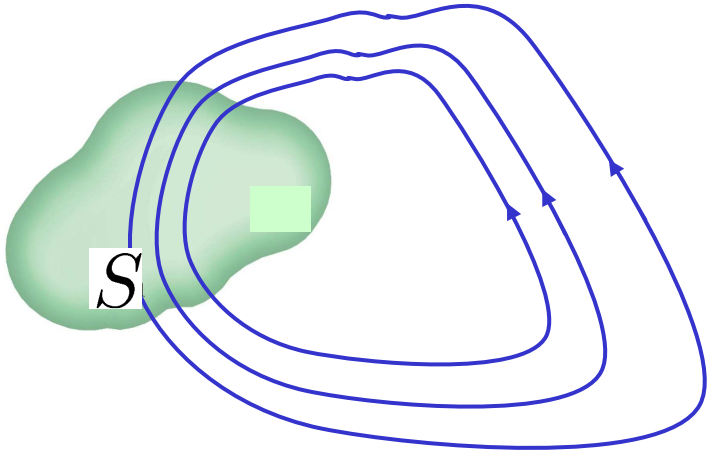



S
N

Primera llei de la magnetostàtica

El flux de camp magnètic per una superfície tancada és zero

$$\oint_S \vec{B} \cdot d\vec{s} = 0$$



Les línies de camp magnètic són tancades
No hi ha "càrregues magnètiques"

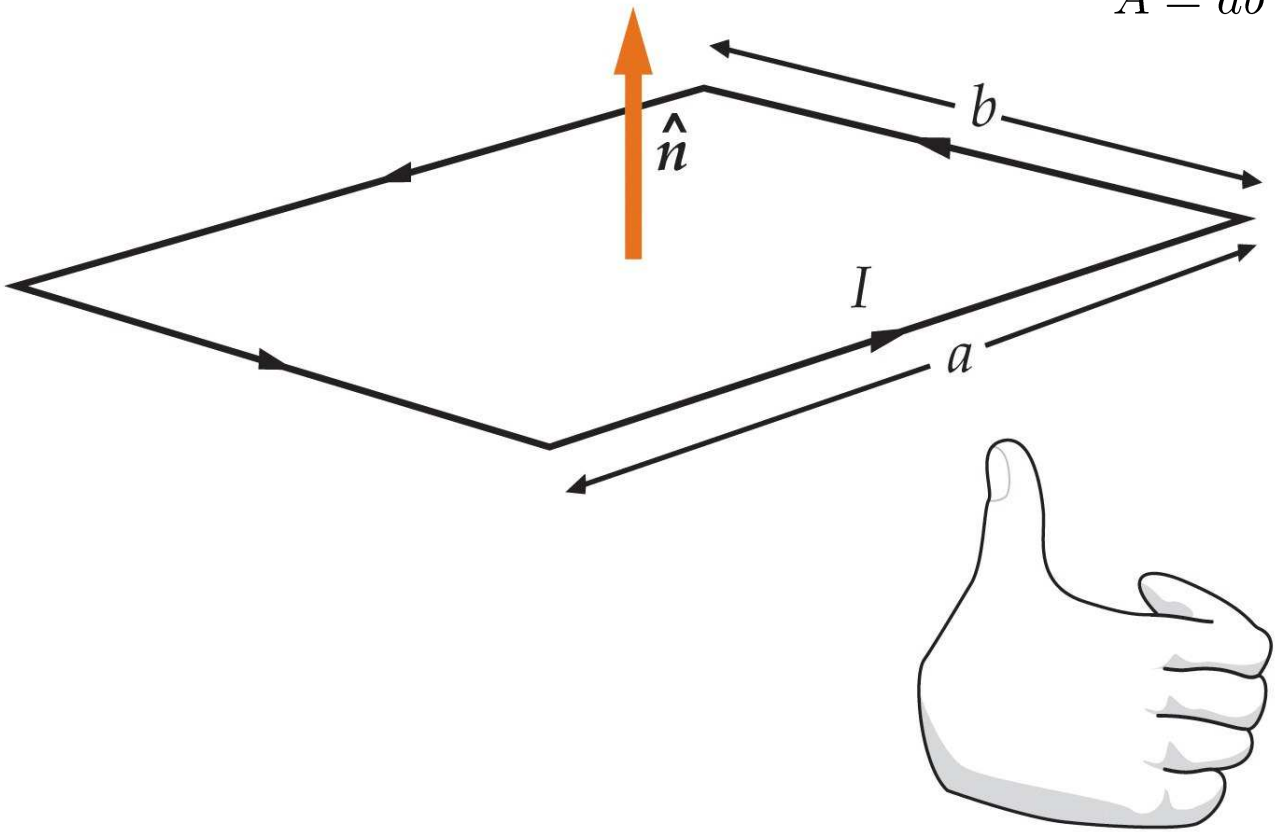
Moments de força sobre espires de corrent i imants

Moment dipolar magnètic (*moment magnètic*)

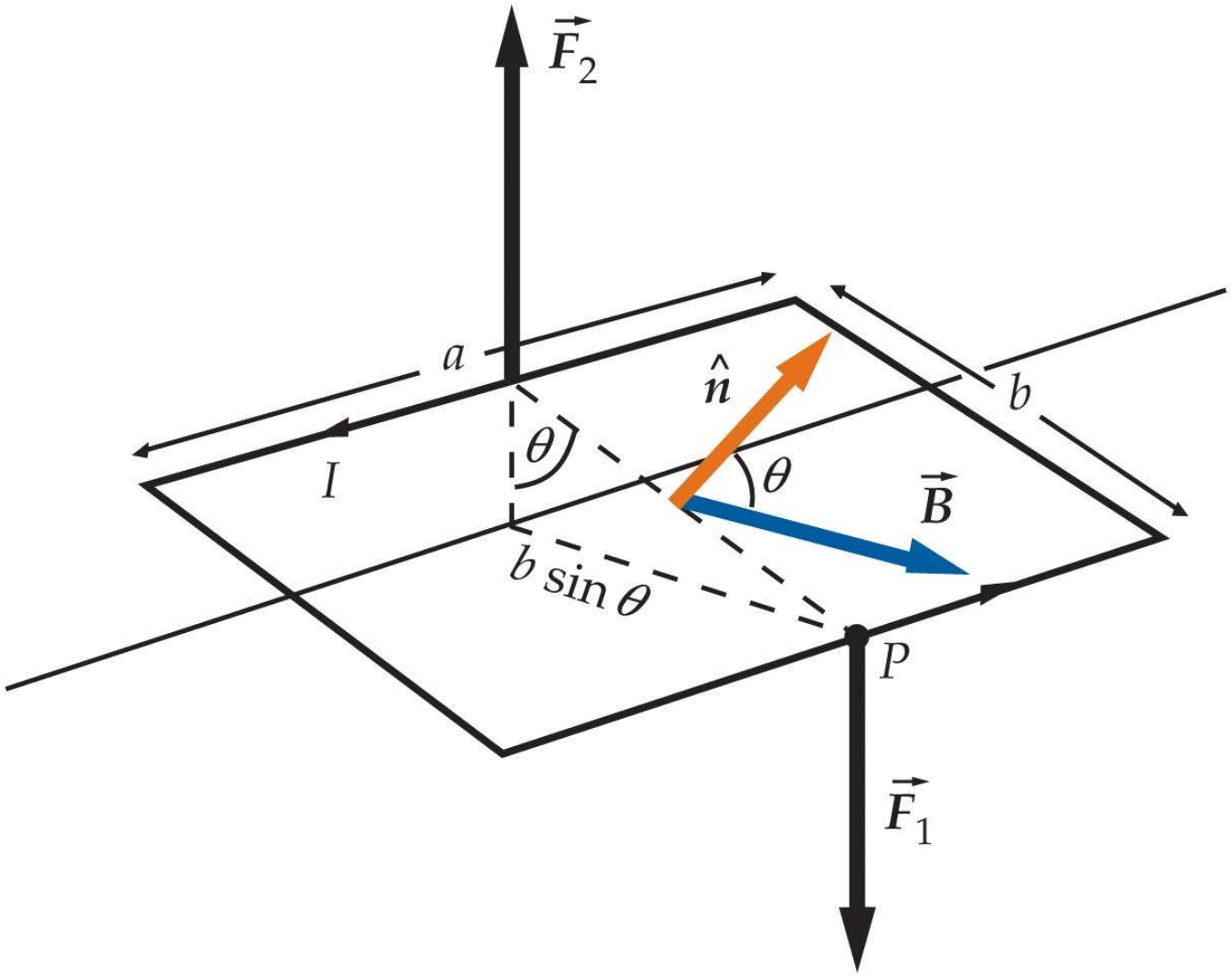
D'una espira de corrent

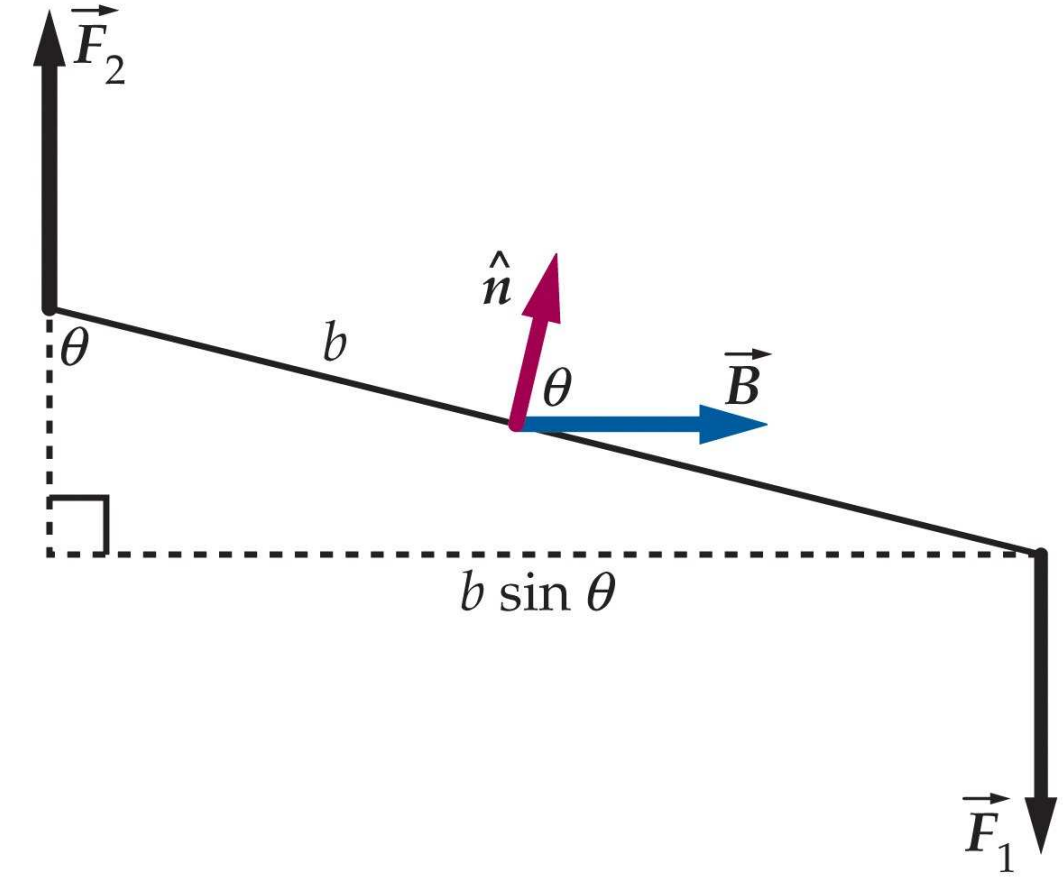
$$\vec{\mu} = I\,A\,\hat{n}$$

$$A = ab$$



Espira dins un camp magnètic



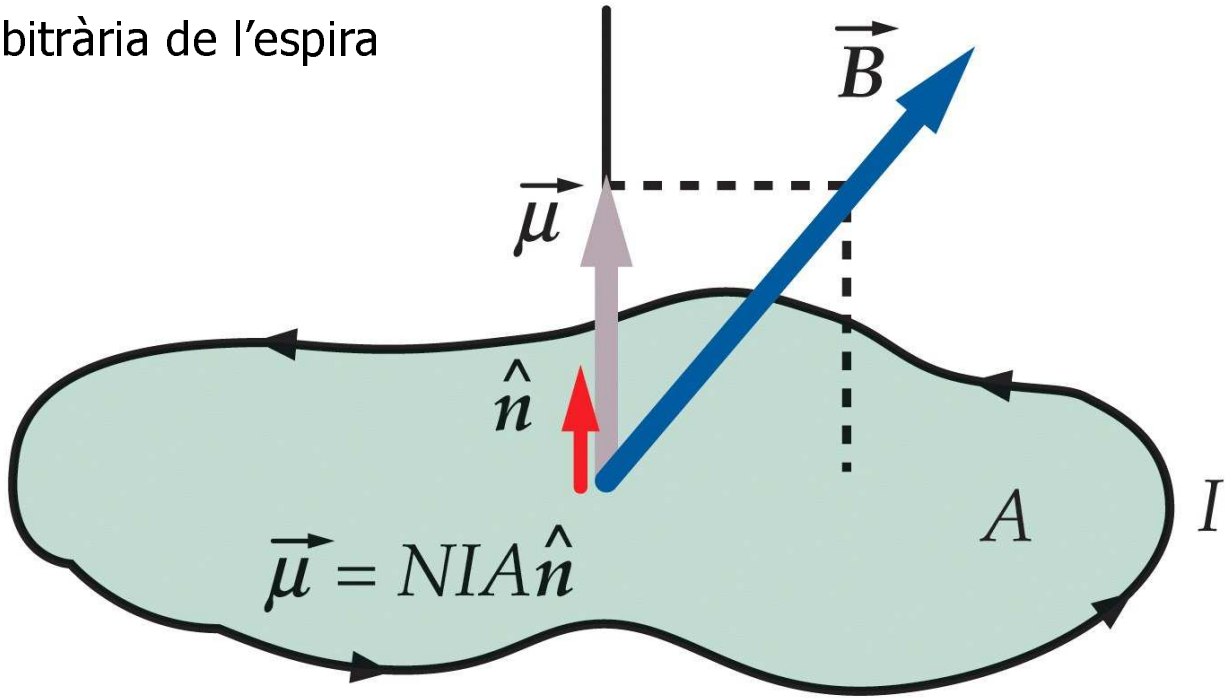


$$F_1 = F_2 = IaB$$

$$\tau = Iab \sin\theta$$

$$\vec{\tau} = \vec{\mu} \times \vec{B} \qquad 26\text{-}15$$

Forma arbitrària de l'espira

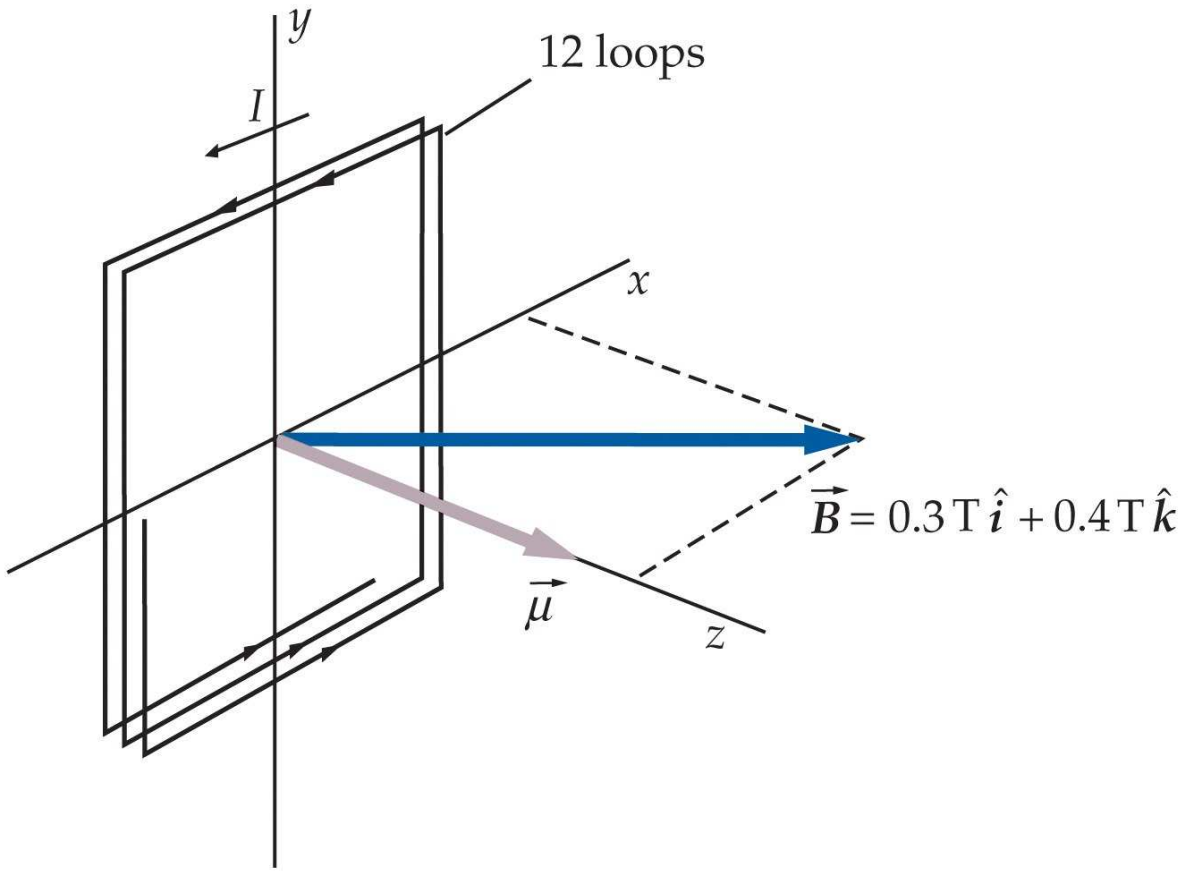


Energia potencial d'una espira dins un camp magnètic

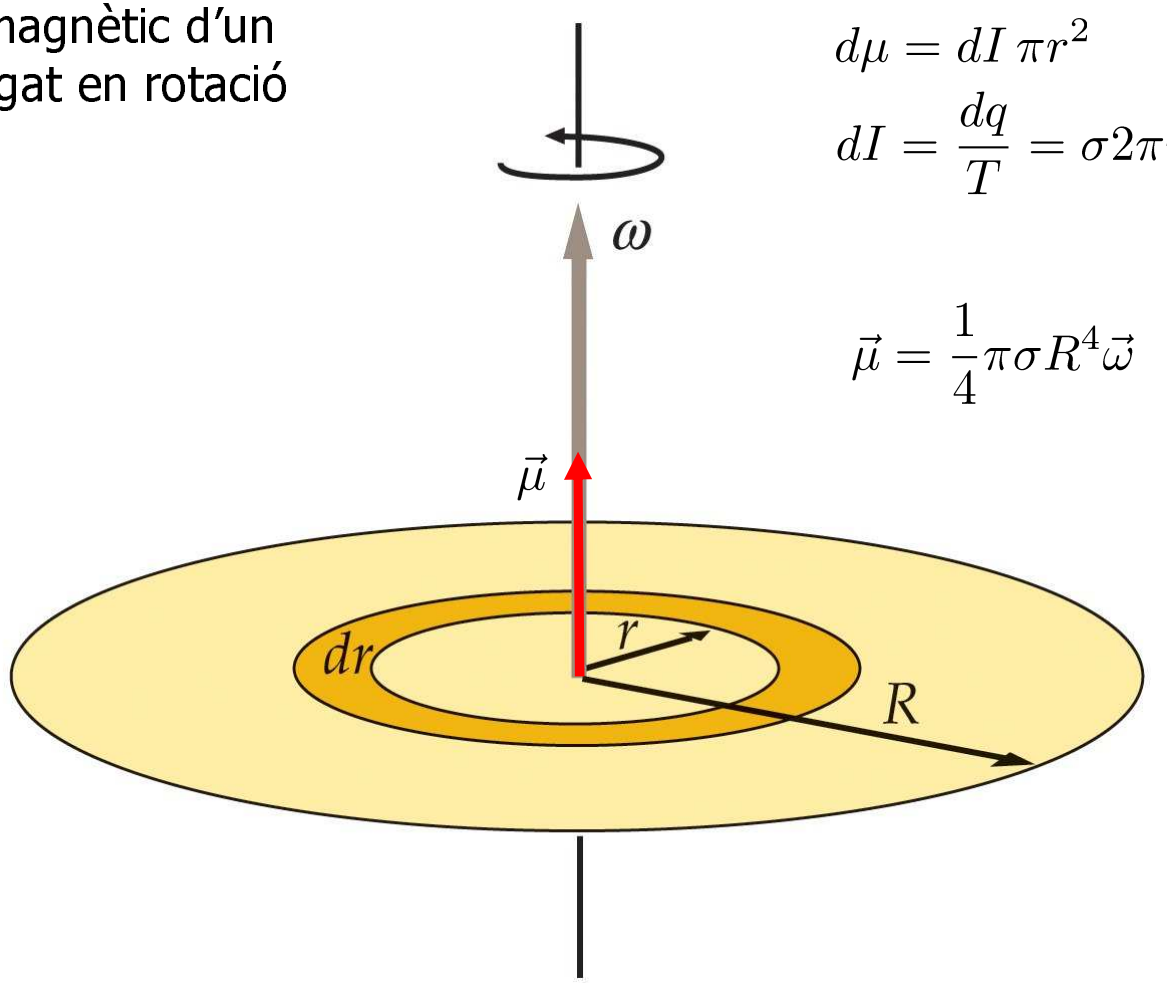
$$U = -\mu B \cos\theta = -\vec{\mu} \cdot \vec{B}$$

Exemples

Moment de força sobre una bobina



Moment magnètic d'un disc carregat en rotació

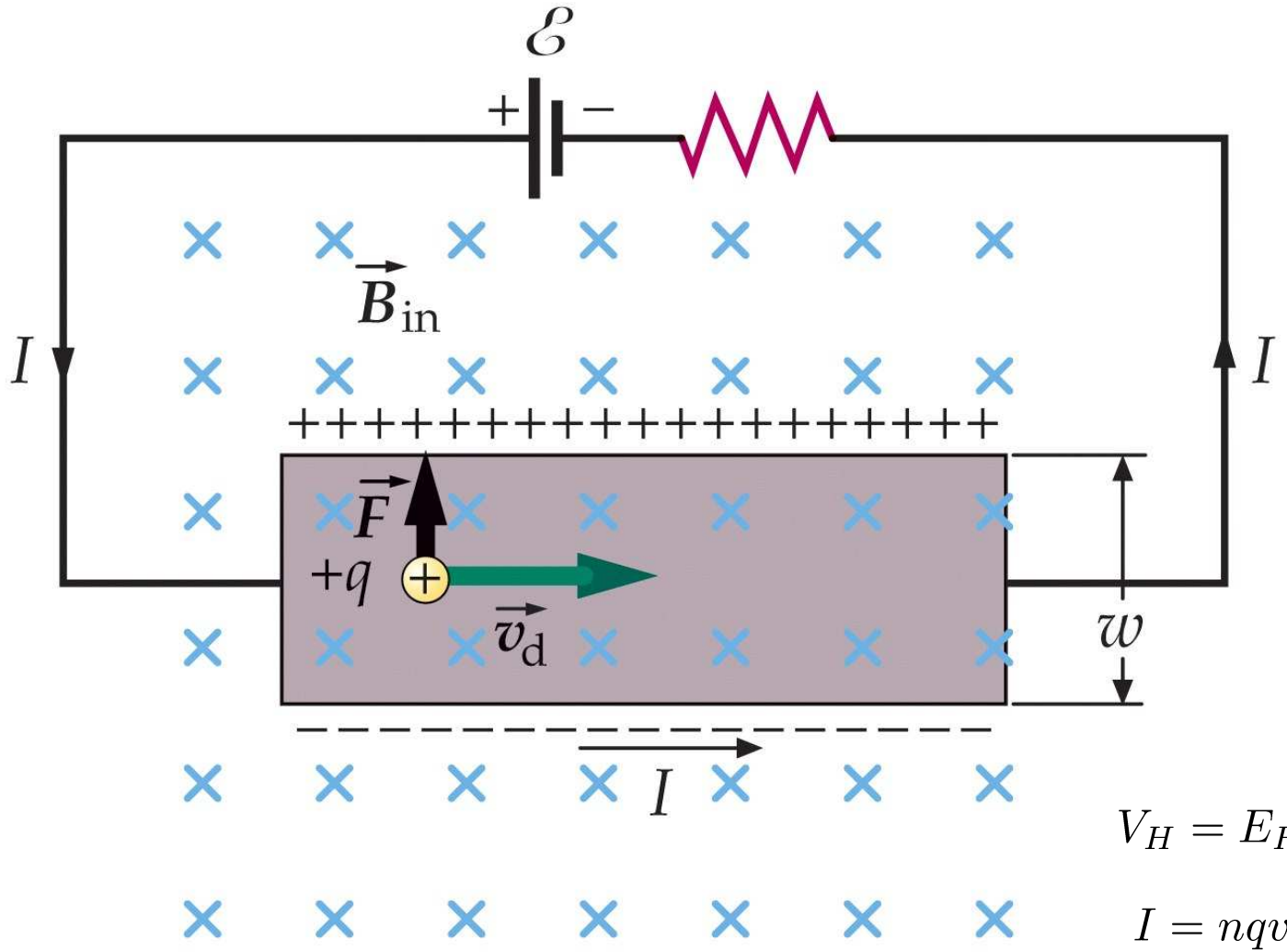


$$d\mu = dI\,\pi r^2$$

$$dI = \frac{dq}{T} = \sigma 2\pi r dr \frac{\omega}{2\pi} = \sigma \omega r dr$$

$$\vec{\mu} = \frac{1}{4}\pi\sigma R^4 \vec{\omega}$$

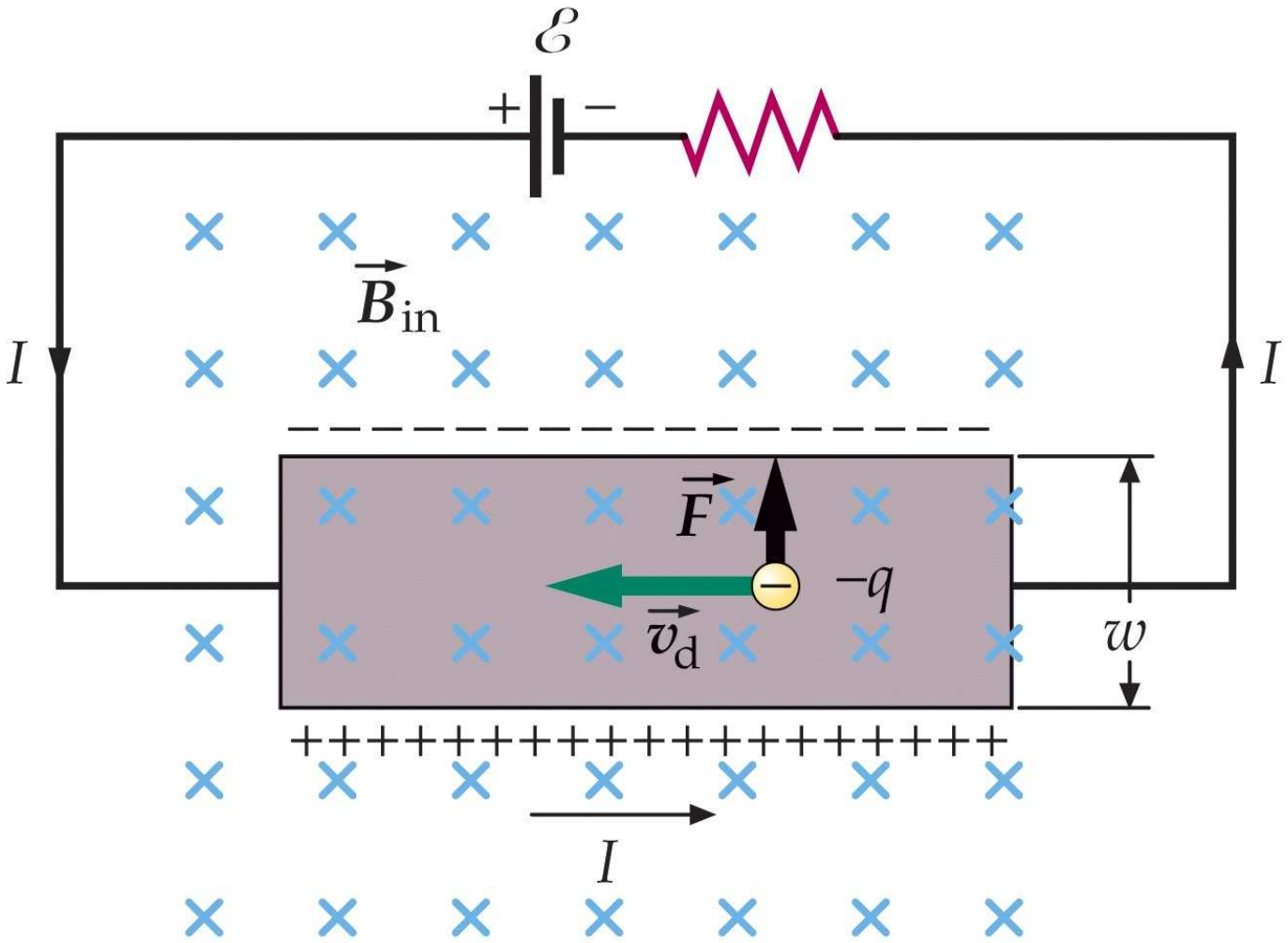
L'efecte Hall



$$V_H = E_H w = v_d B w$$

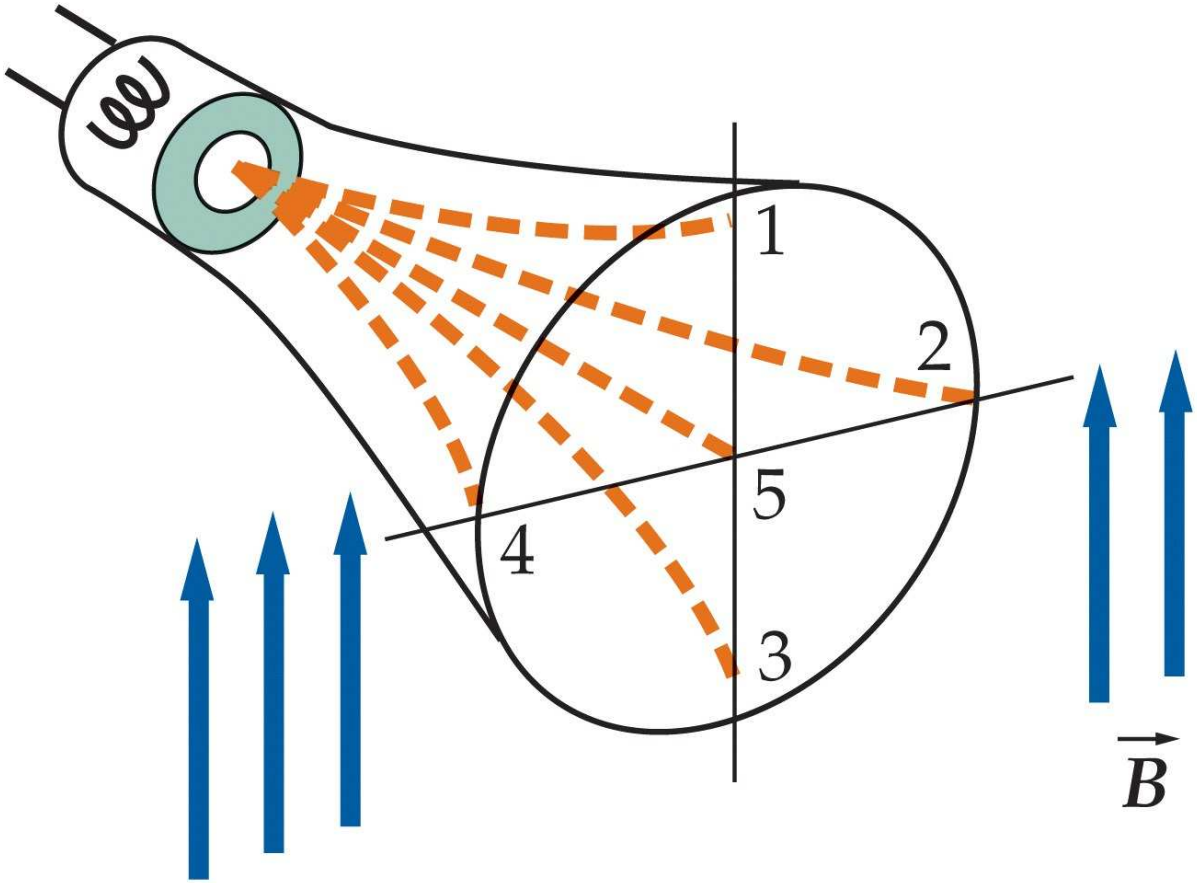
$$I = nqv_d A \qquad A \to wt$$

$$V_H = \frac{I}{nqt} B$$ mesura de B

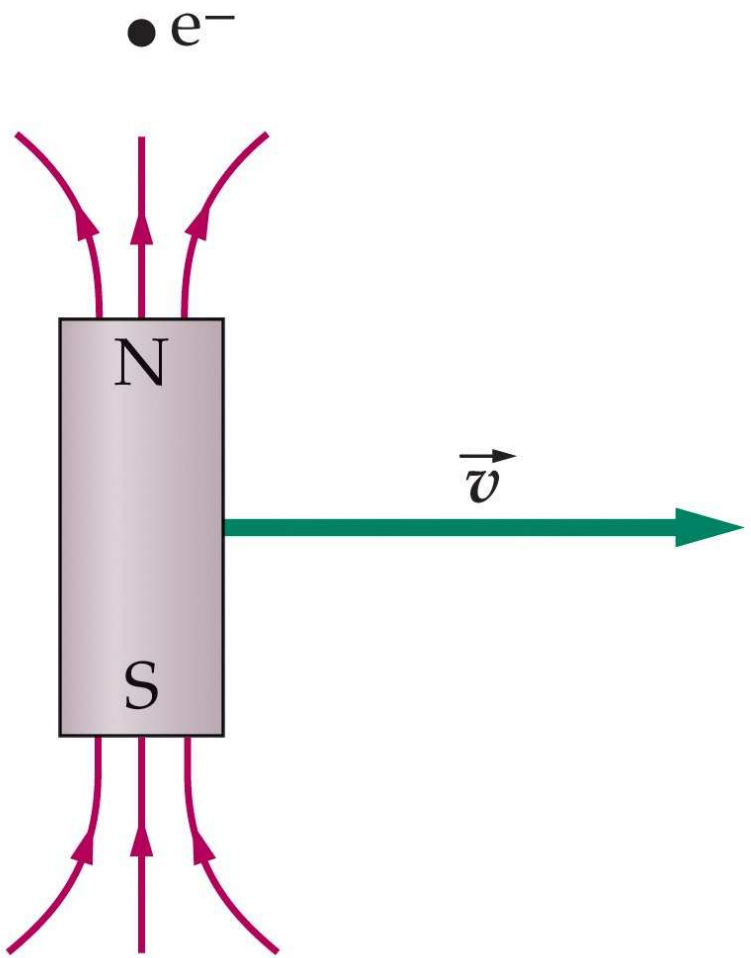

$\mathcal{E}$
+
−
$\vec{B}_{\text{in}}$
I
I
$\vec{F}$
$-q$
$\vec{v}_{\text{d}}$
w
I

Problems

26.1



26.13



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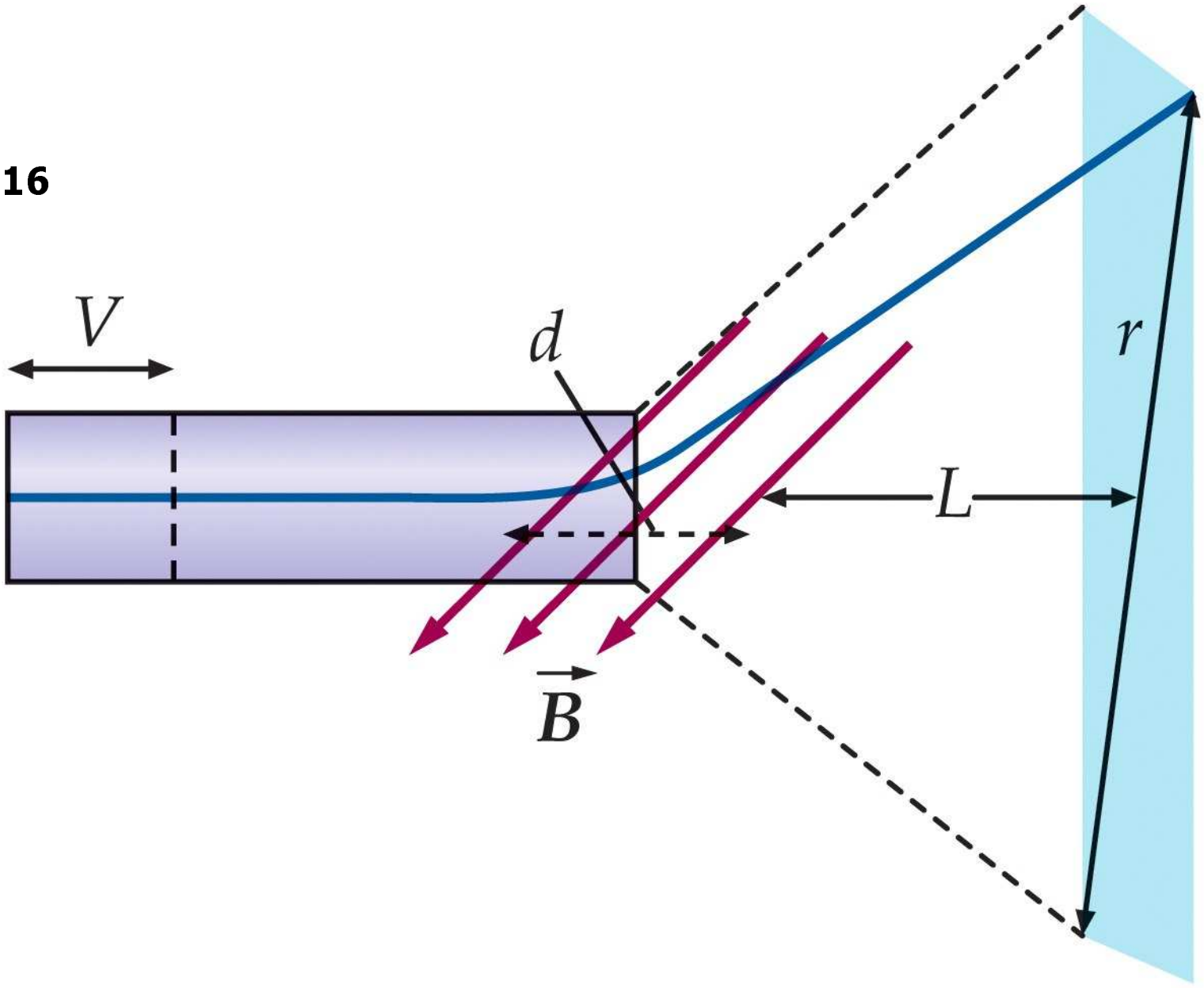

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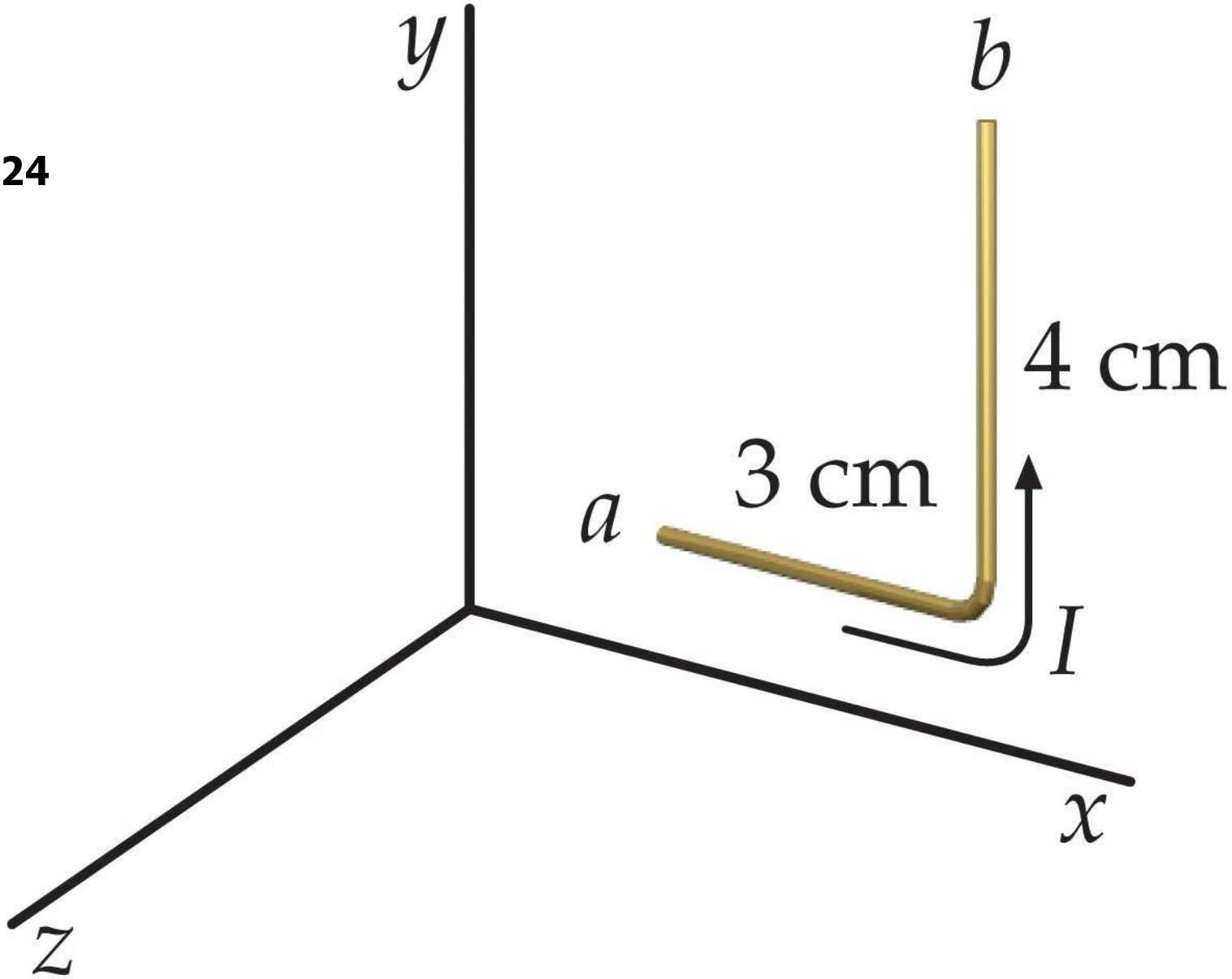

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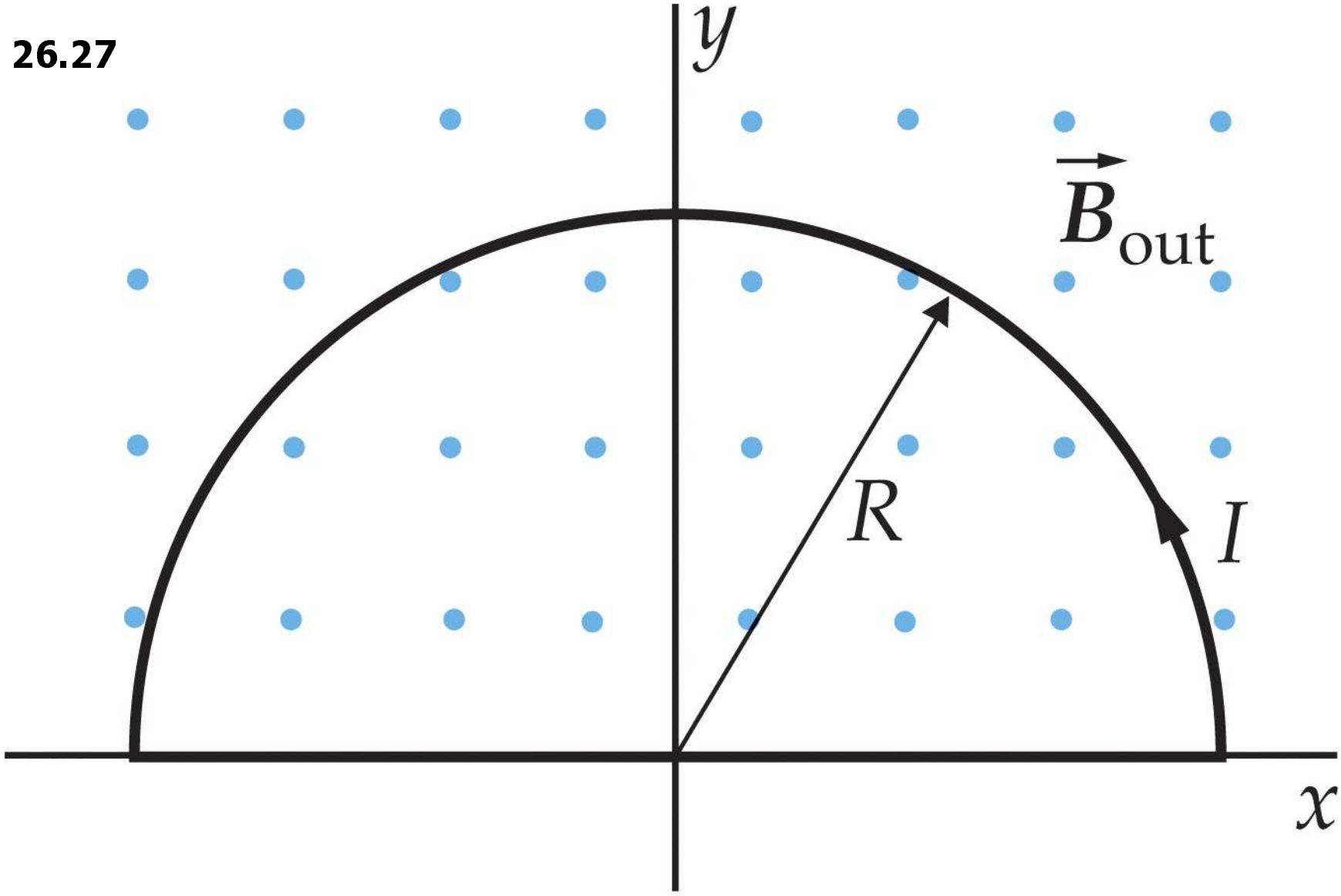
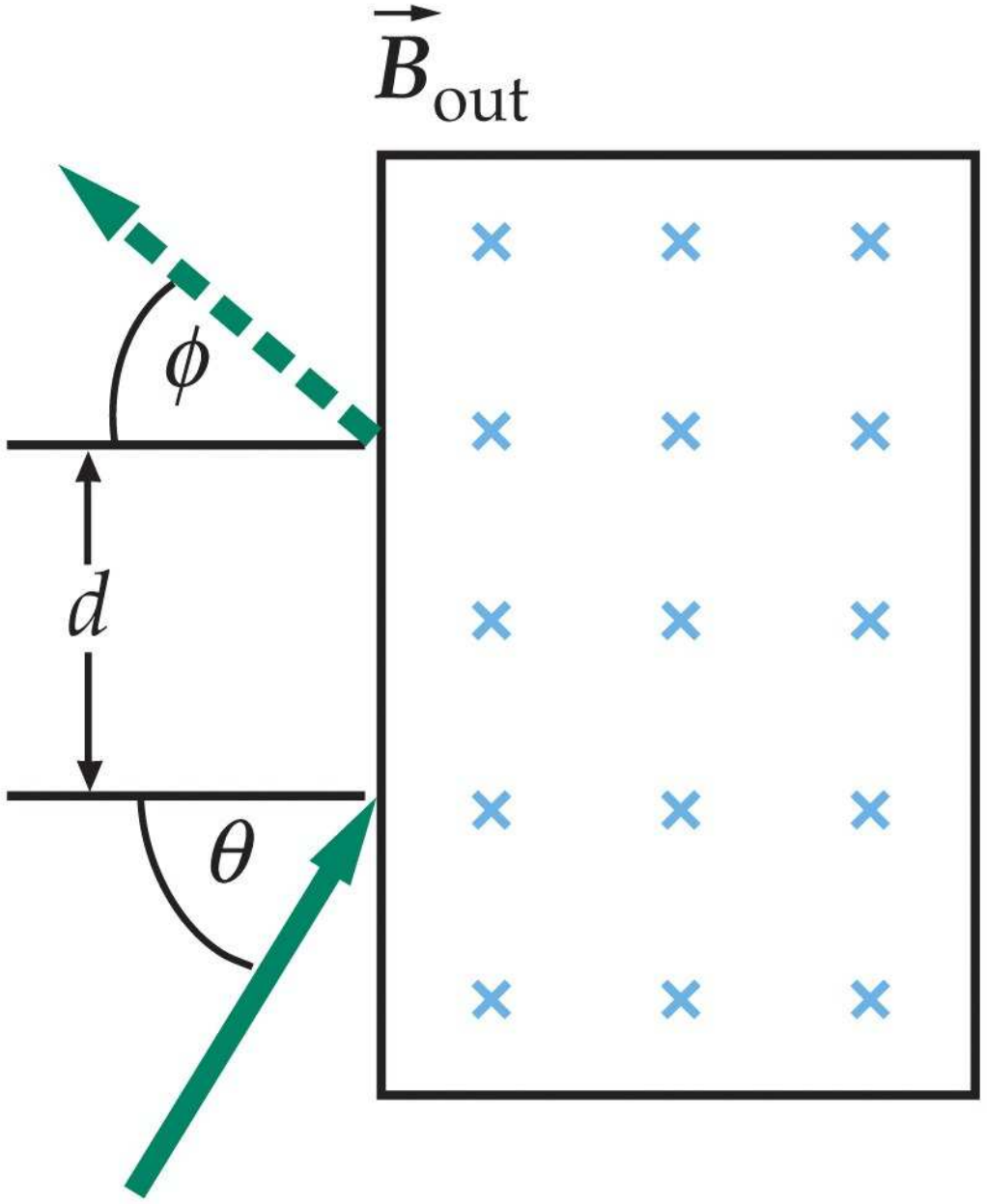


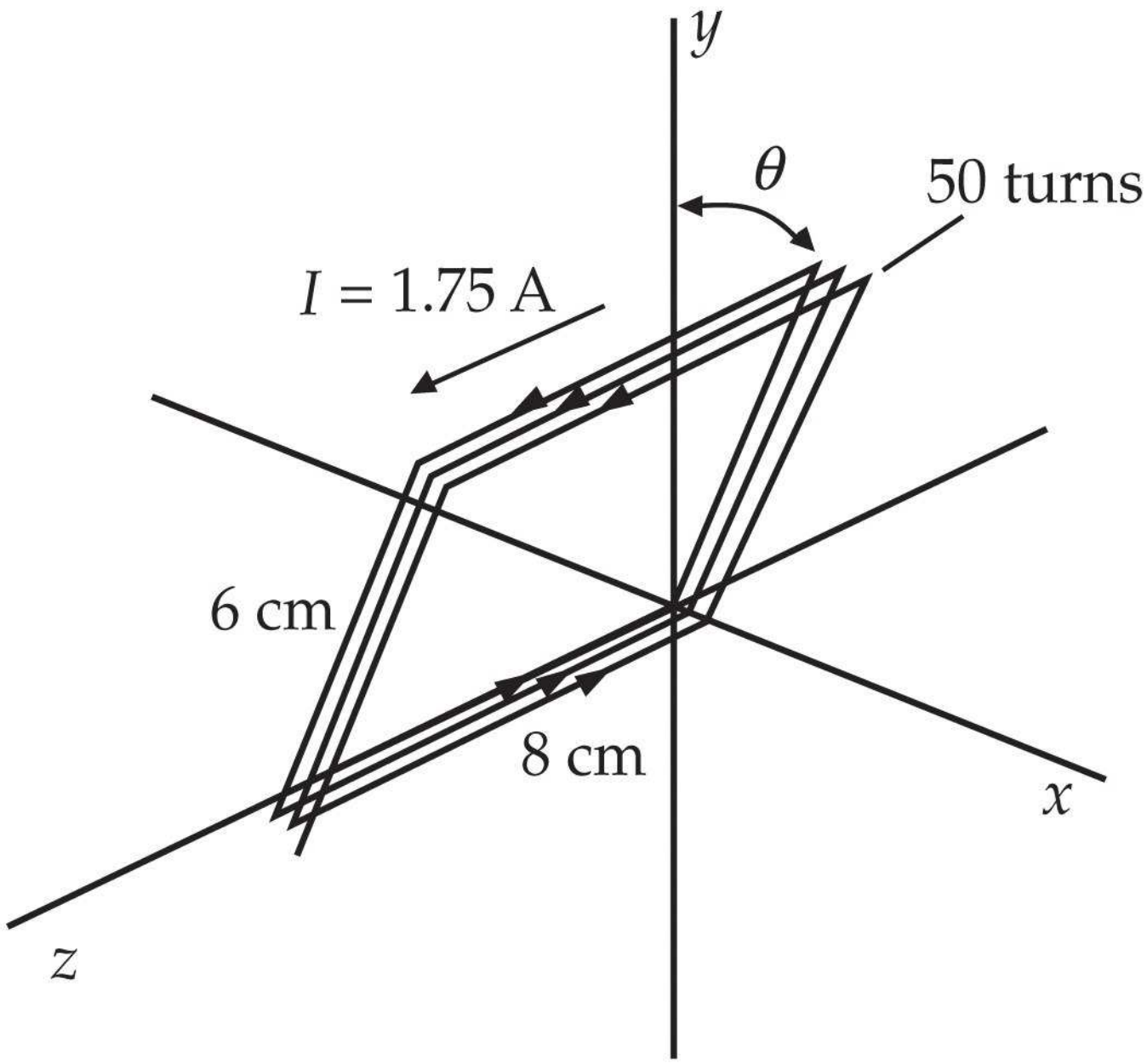
26.38

26.39

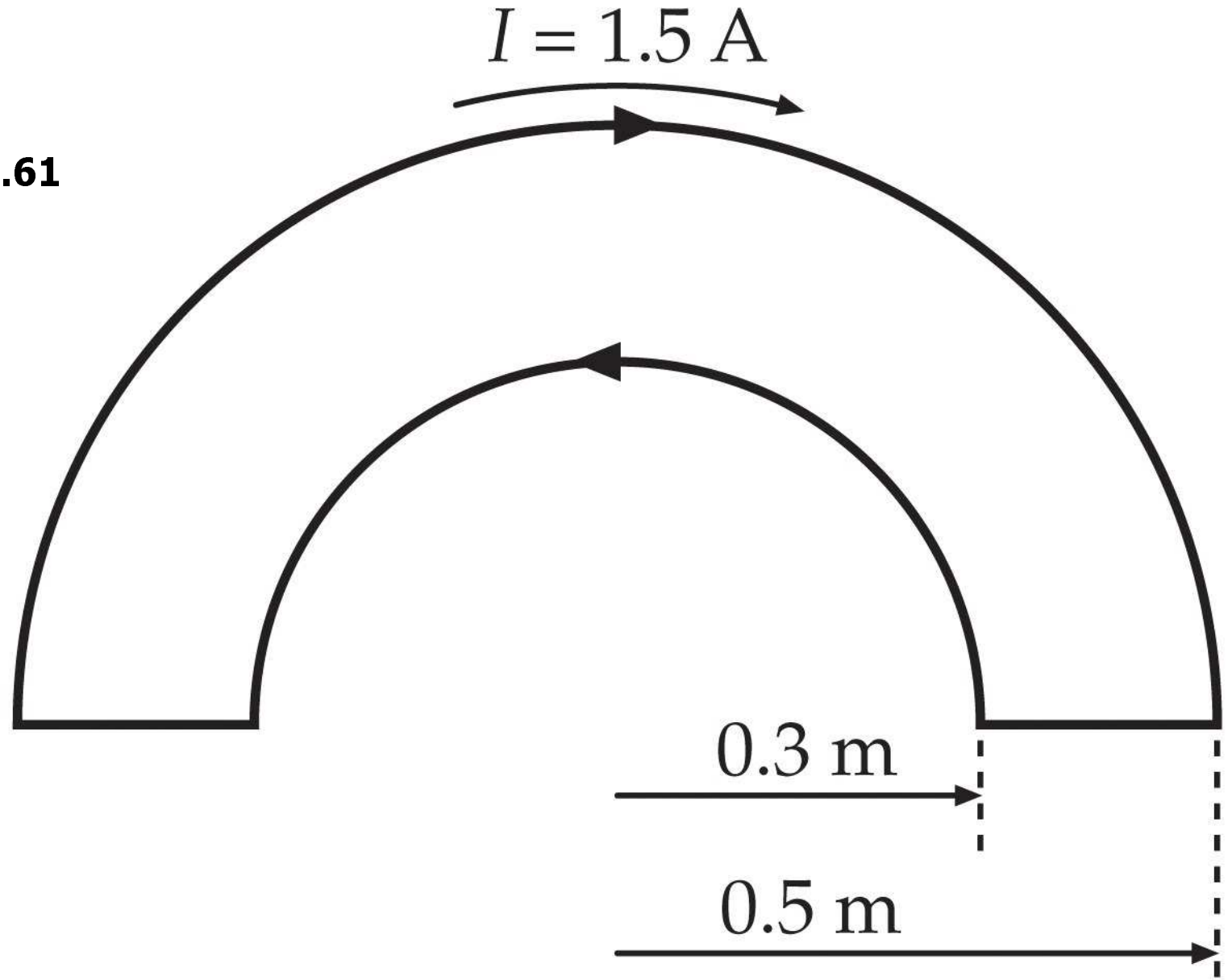


26.58

26.59



26.61



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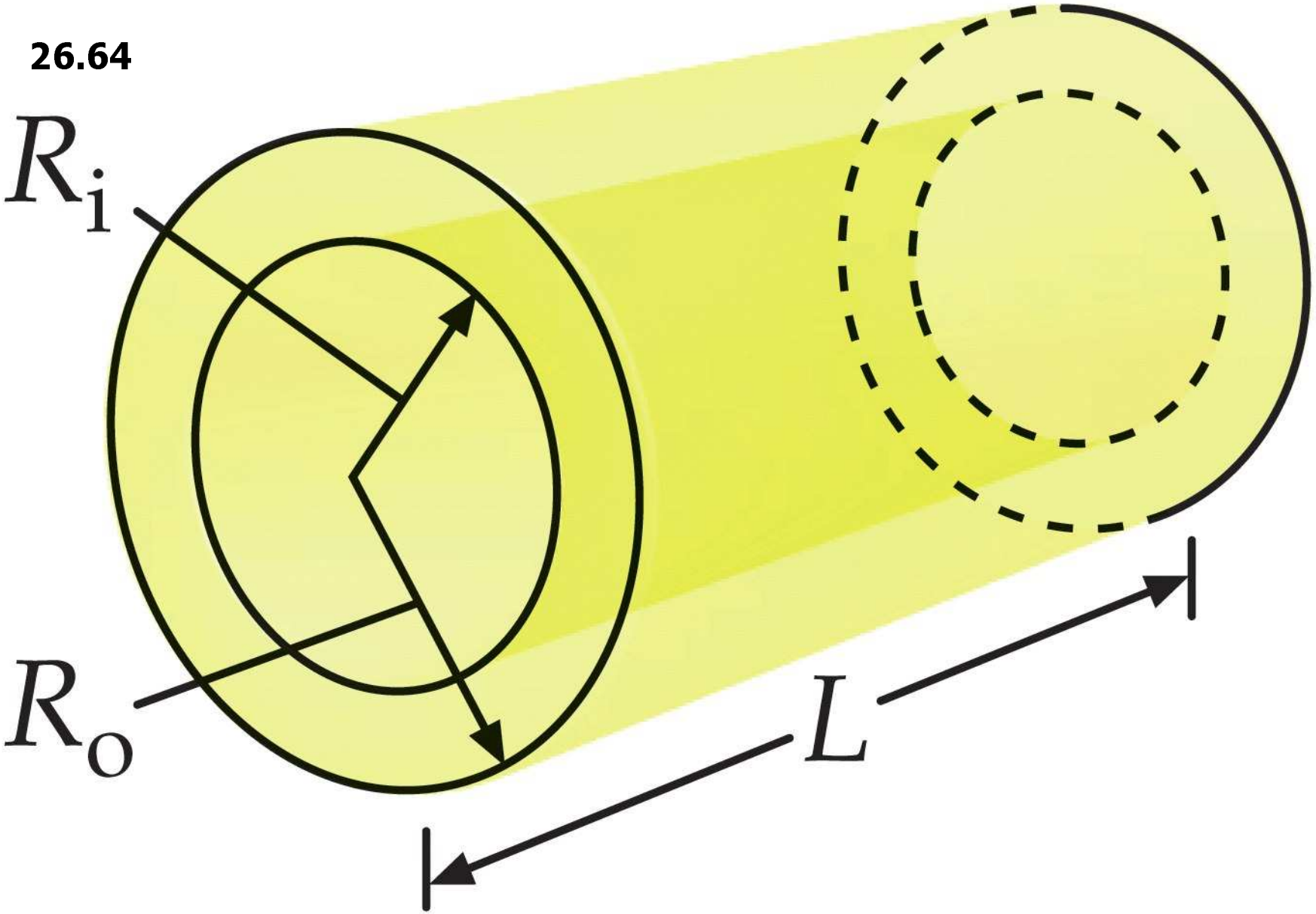

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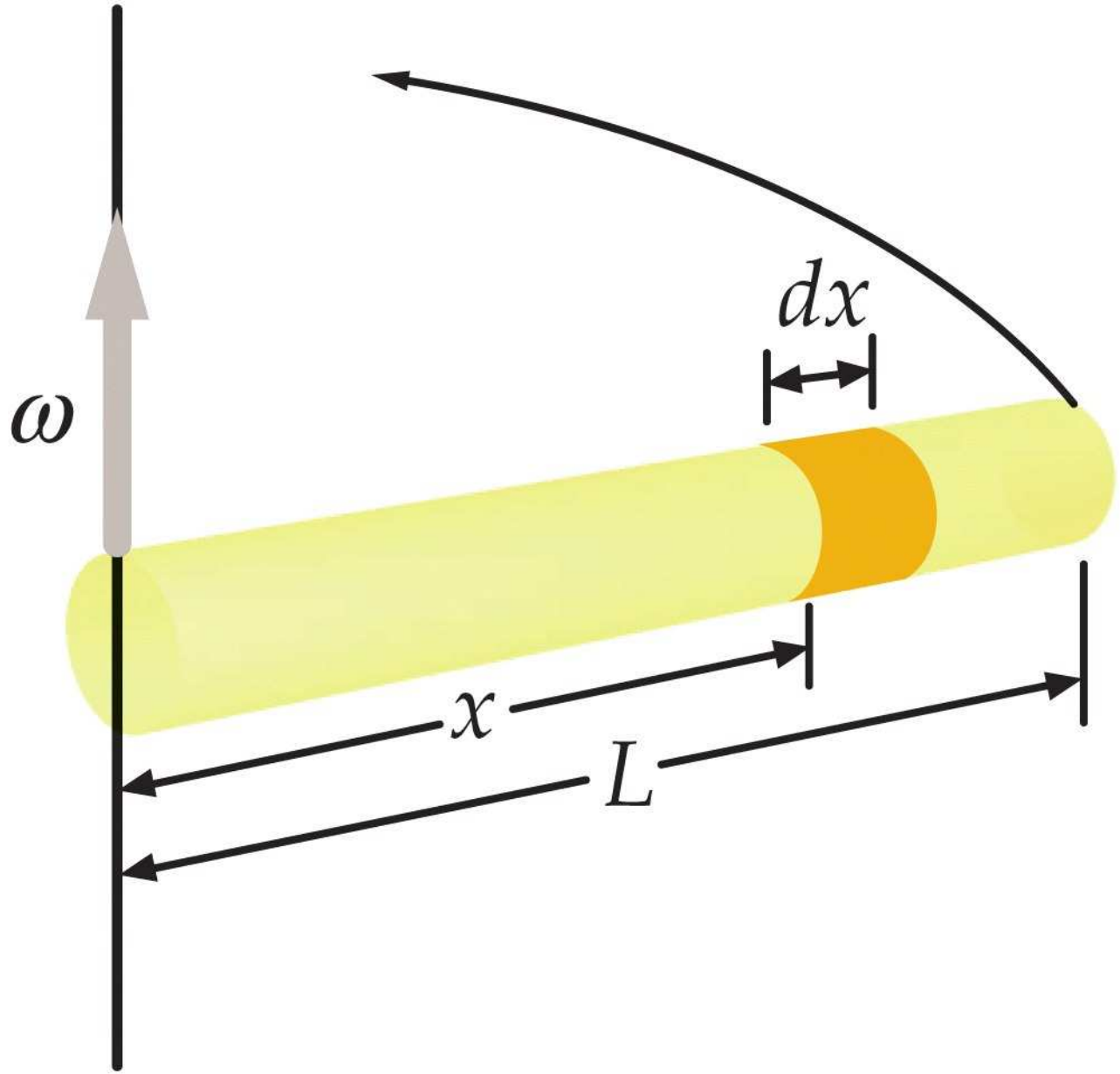

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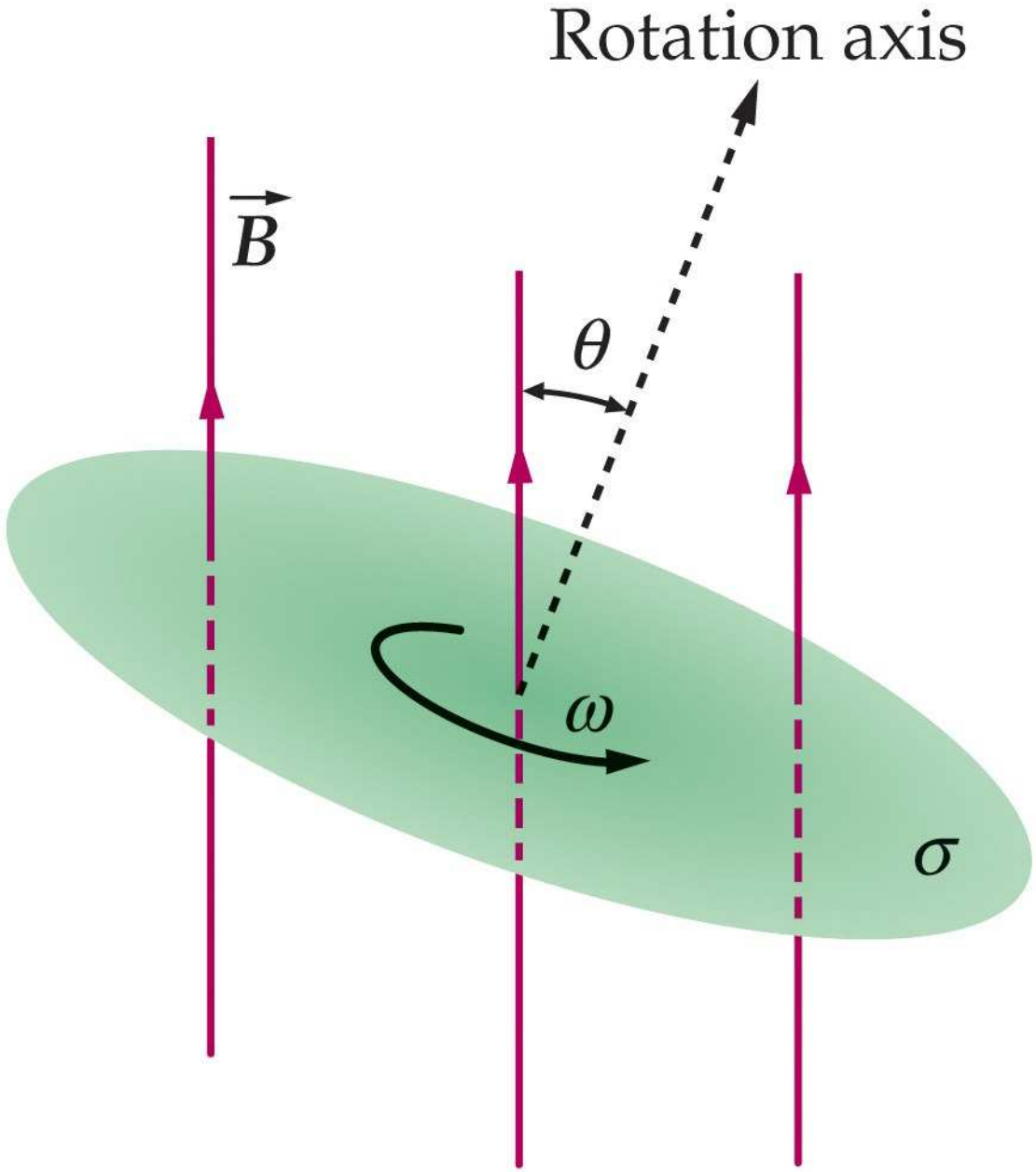
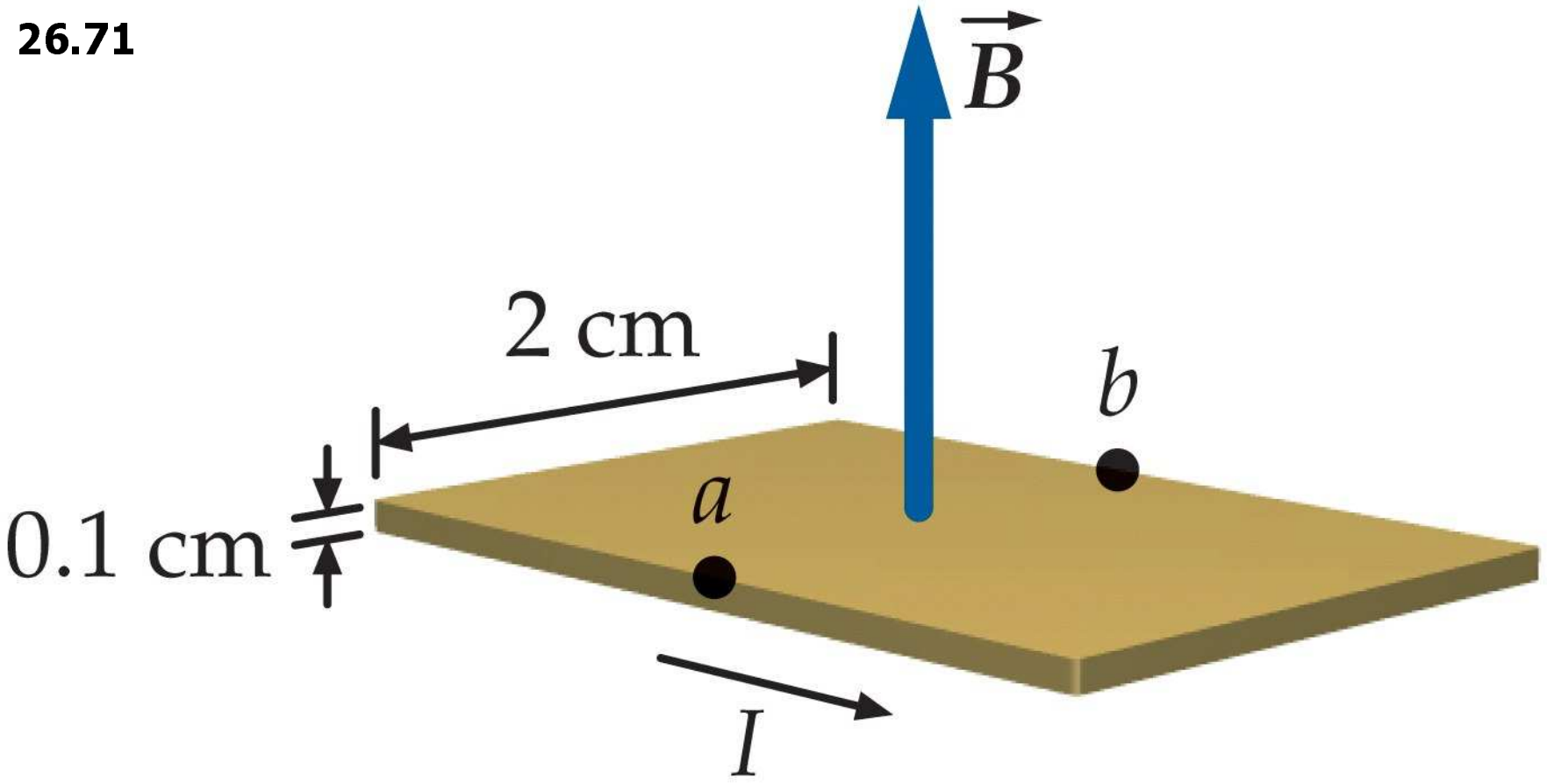
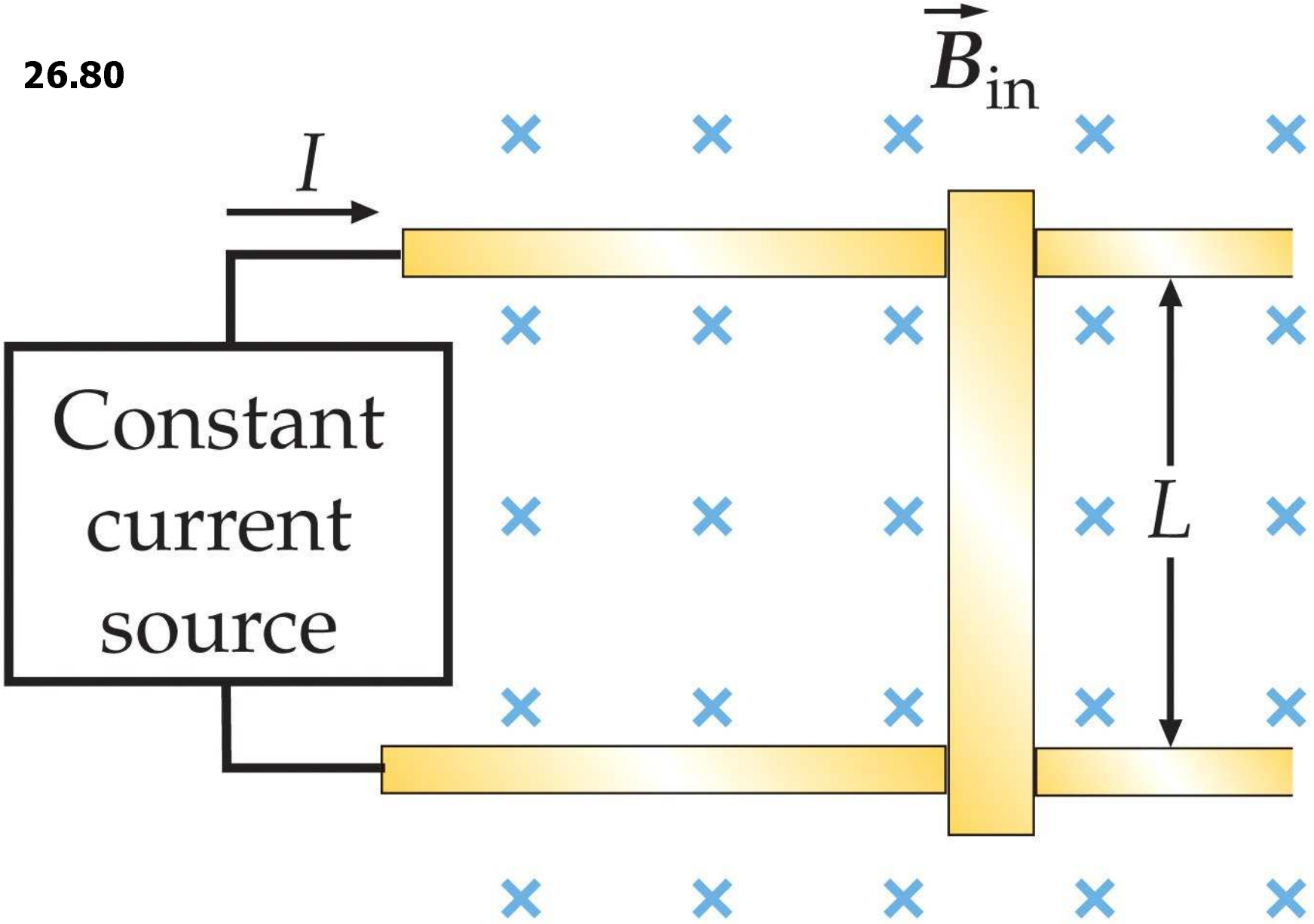


26.70

26.71



26.80



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