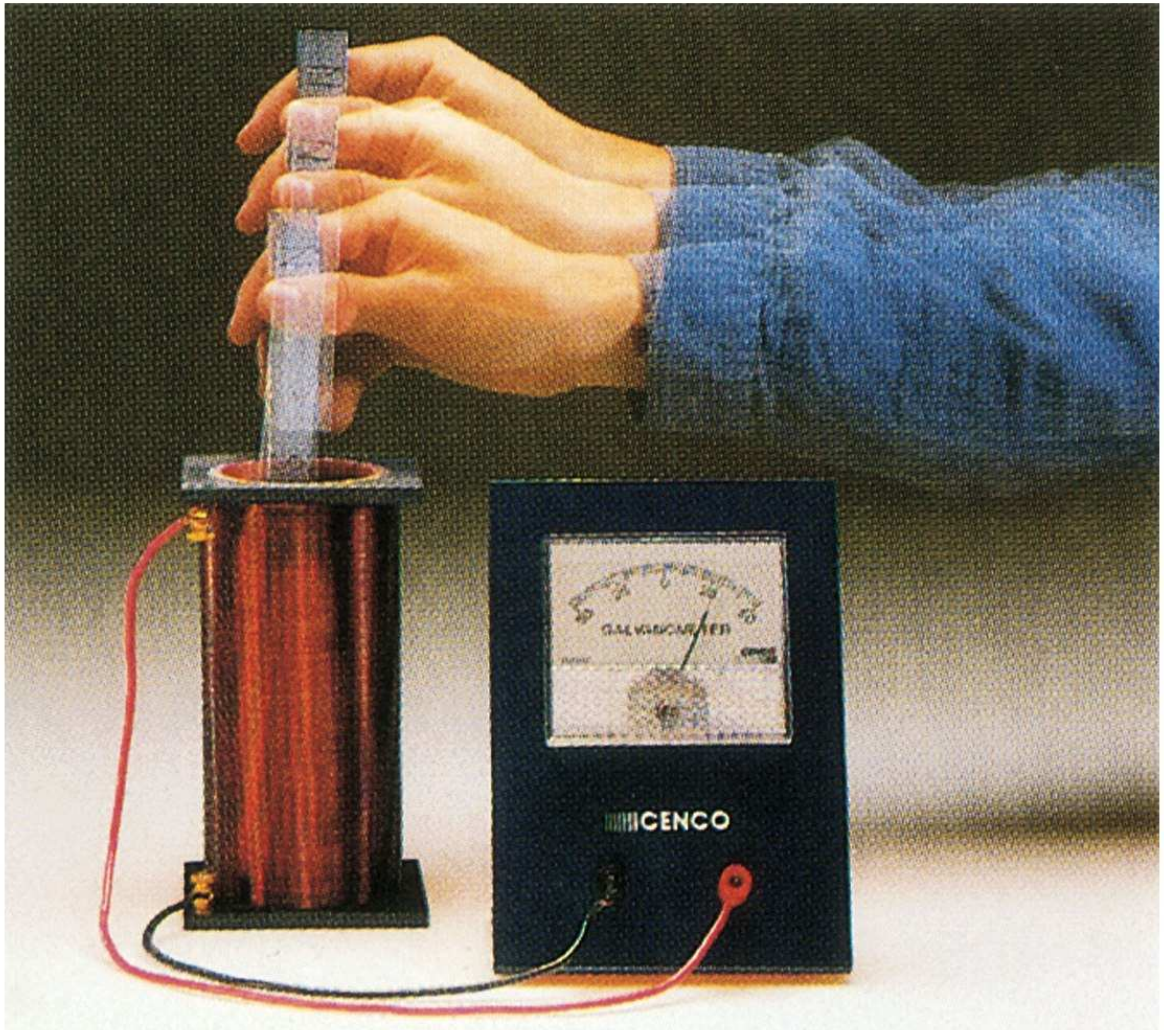
Inducció Magnètica

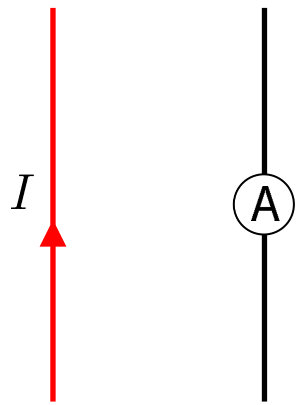

GALVANOMETER
CENCO

Hem vist:

Un corrent elèctric estacionari produeix un camp magnètic

Un camp magnètic pot produir un camp elèctric?

No en situacions estàtiques

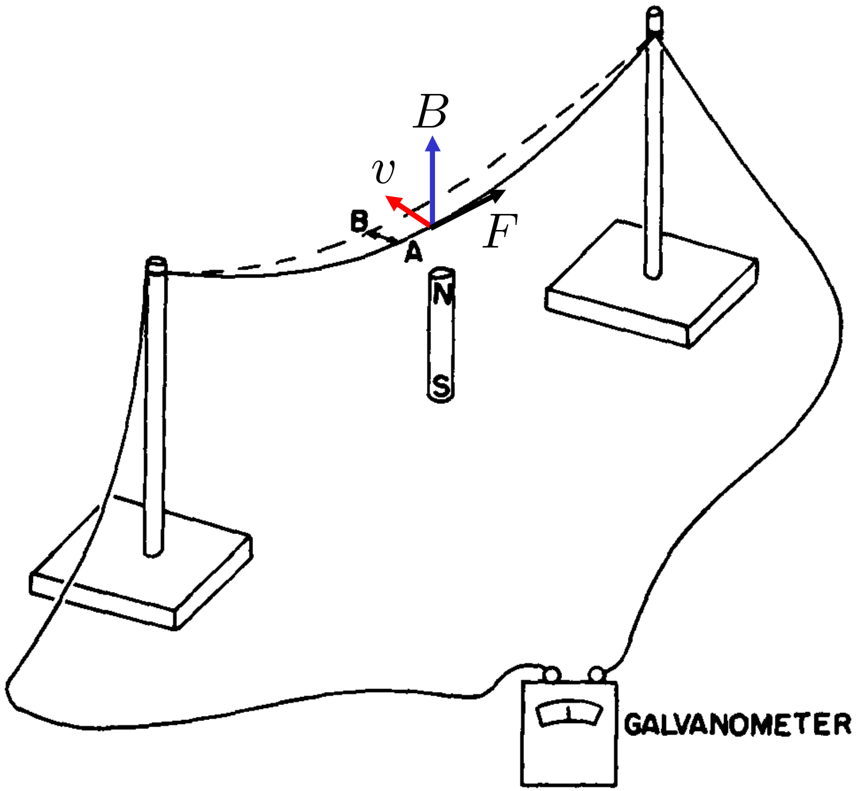


El corrent a un fil no indueix l'aparició de corrent a l'altre

Faraday va descobrir que per induir l'aparició de camps elèctrics a partir de camps magnètics fan falta situacions dinàmiques, amb canvis temporals.

Relativitat del moviment

Força de Lorentz



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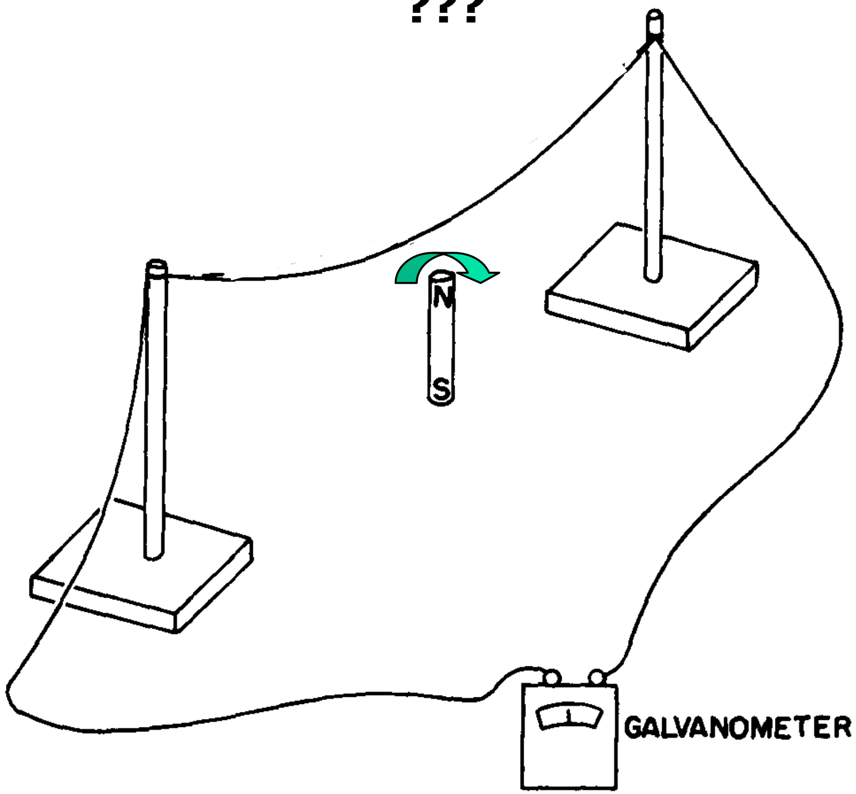
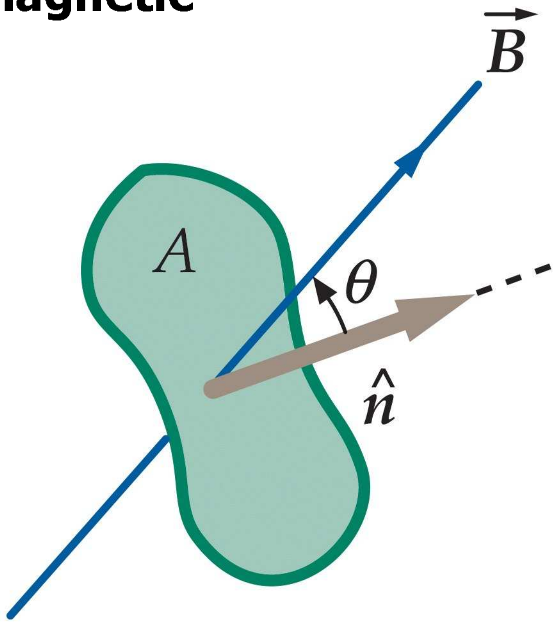
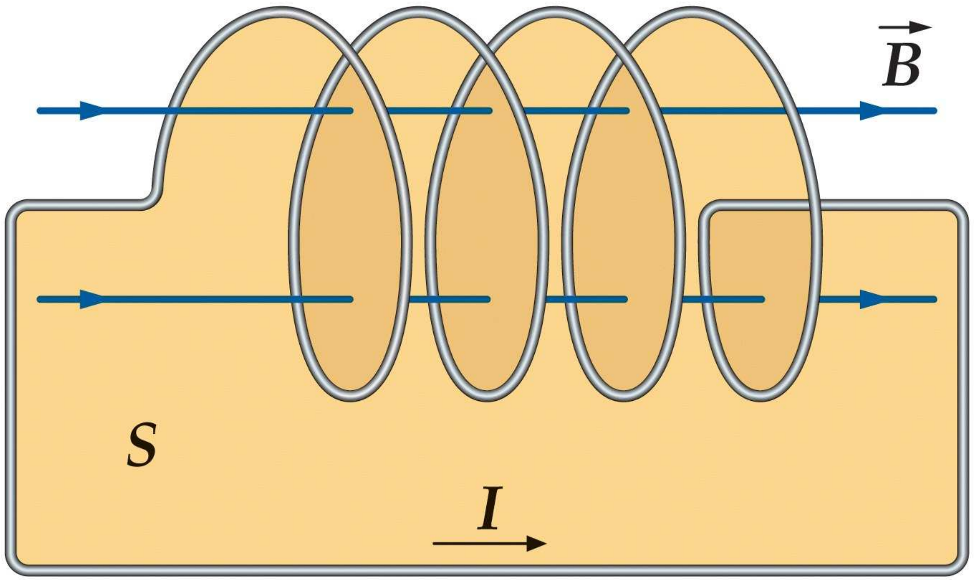


Flux magnètic

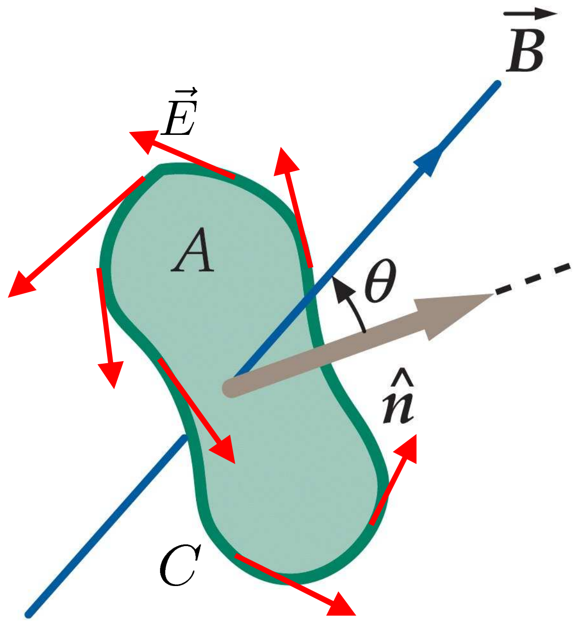


$$\phi_m = \int_S \vec{B} \cdot d\vec{s}$$

$$\phi_m = \int_S \vec{B} \cdot \hat{n}\, dA = \int_S B_n\, dA$$



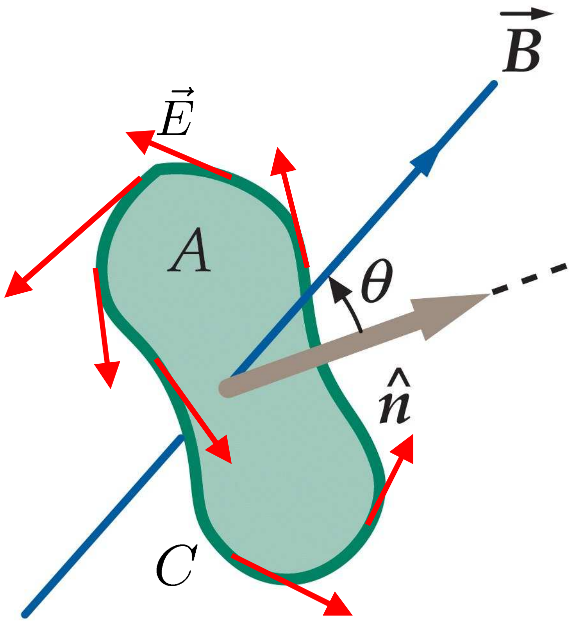
f.e.m. $\mathcal{E}$ (força electromotriu) a una corba tancada C



$\mathcal{E}$: component tangencial mitjana del camp elèctric multiplicat per la longitud

$$\mathcal{E} = \oint_C \vec{E} \cdot d\vec{\ell}$$

La llei de Faraday



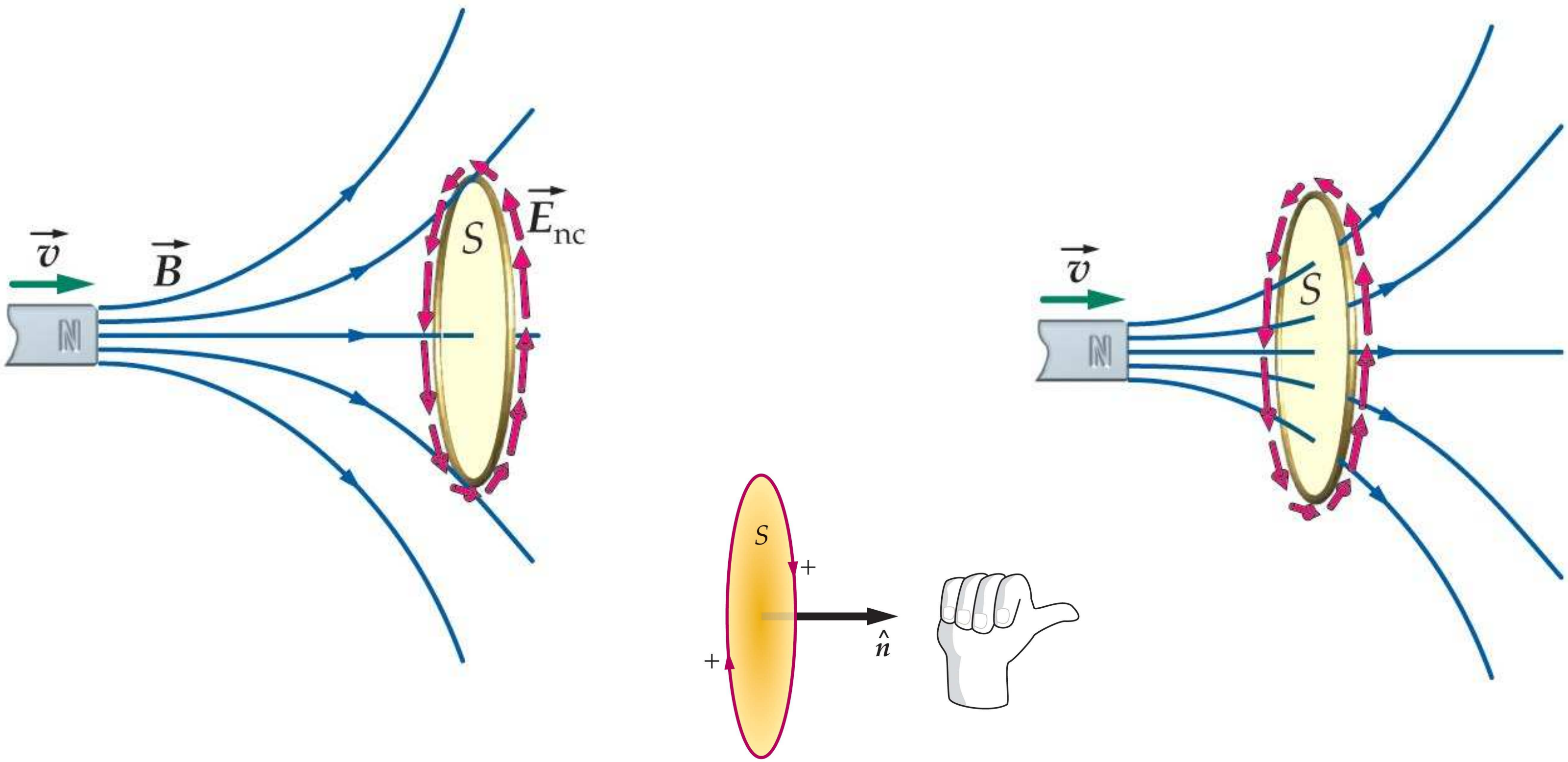
$$\boxed{\mathcal{E} = -\frac{d\phi_m}{dt}}$$

$$\oint_C \vec{E} \cdot d\vec{\ell} = -\frac{d}{dt} \int_A \vec{B} \cdot d\vec{s}$$

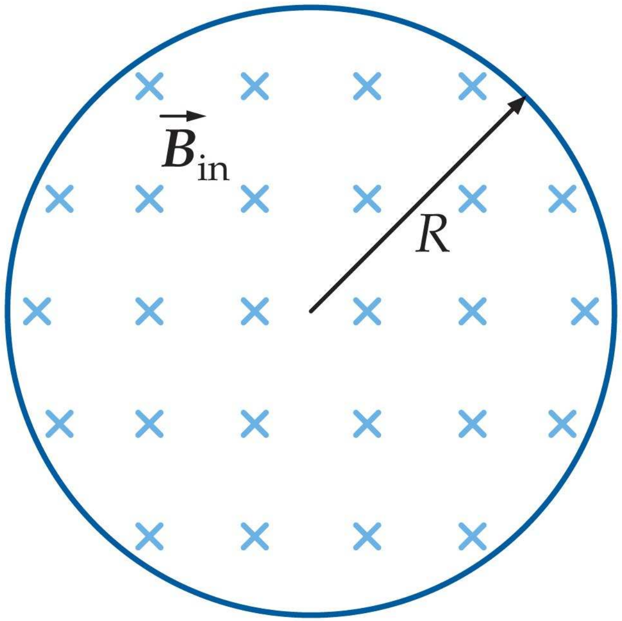
Generalització de la llei electrostàtica

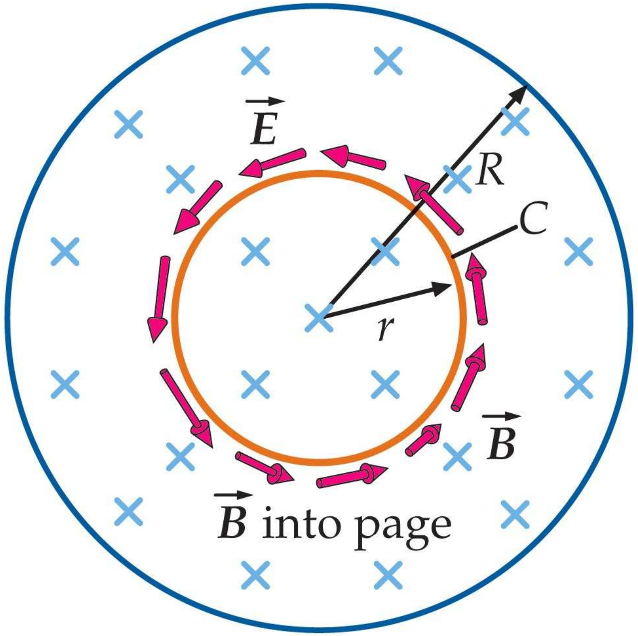
$$\mathcal{E} = \oint_C \vec{E}_{\text{nc}} \cdot d\vec{\ell} = -\frac{d}{dt}\int_S \vec{B}\cdot\hat{n}\,dA = -\frac{d\phi_{\text{m}}}{dt} \qquad 28\text{-}5$$

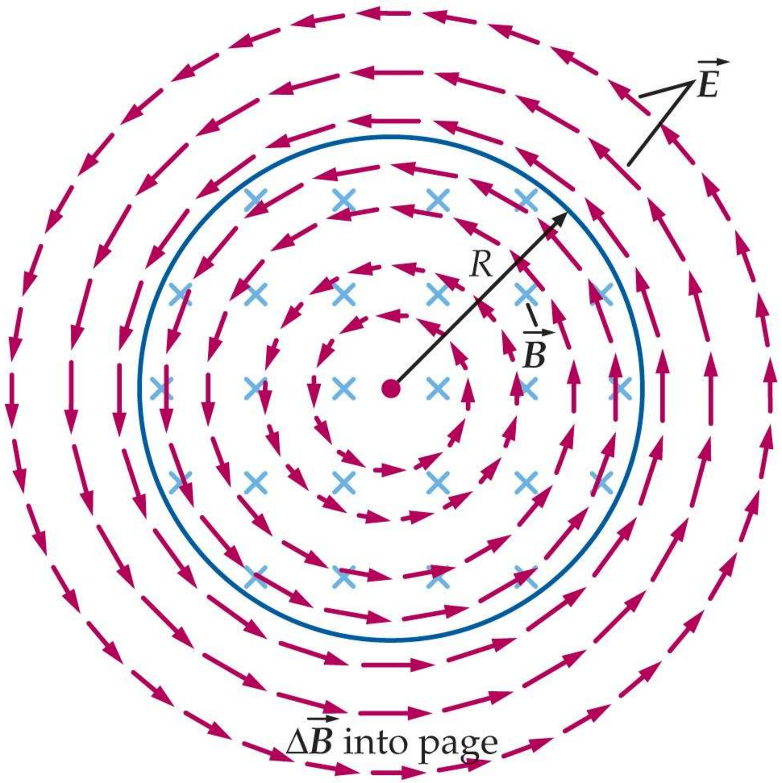
INDUCED EMF IN A STATIONARY CIRCUIT IN A CHANGING MAGNETIC FIELD



Exemple: regió circular amb camp magnètic variable en el temps





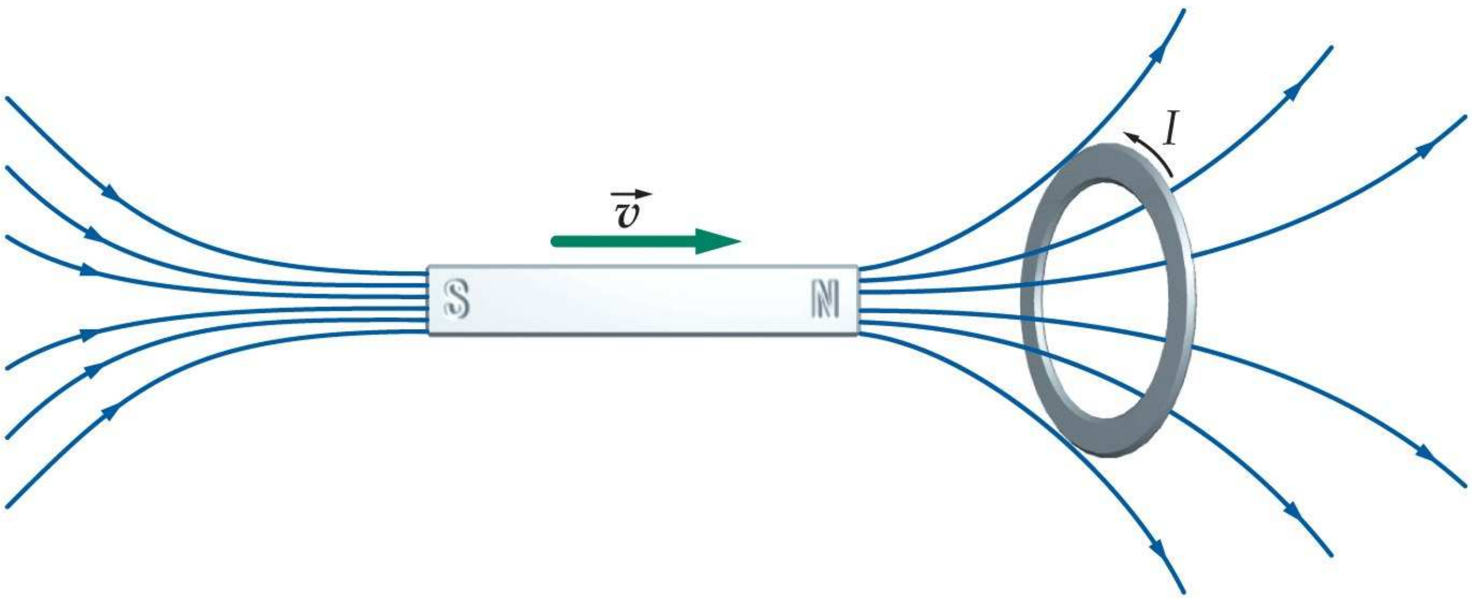


$r < R$	$E 2\pi r = -\dfrac{d}{dt}(B\pi r^2)$	$E = -\dfrac{r}{2}\dfrac{dB}{dt}$
$r > R$	$E 2\pi r = -\dfrac{d}{dt}(B\pi R^2)$	$E = -\dfrac{R^2}{2r}\dfrac{dB}{dt}$

La llei de Lenz

The induced emf is in such a direction as to oppose, or tend to oppose, the change that produces it.

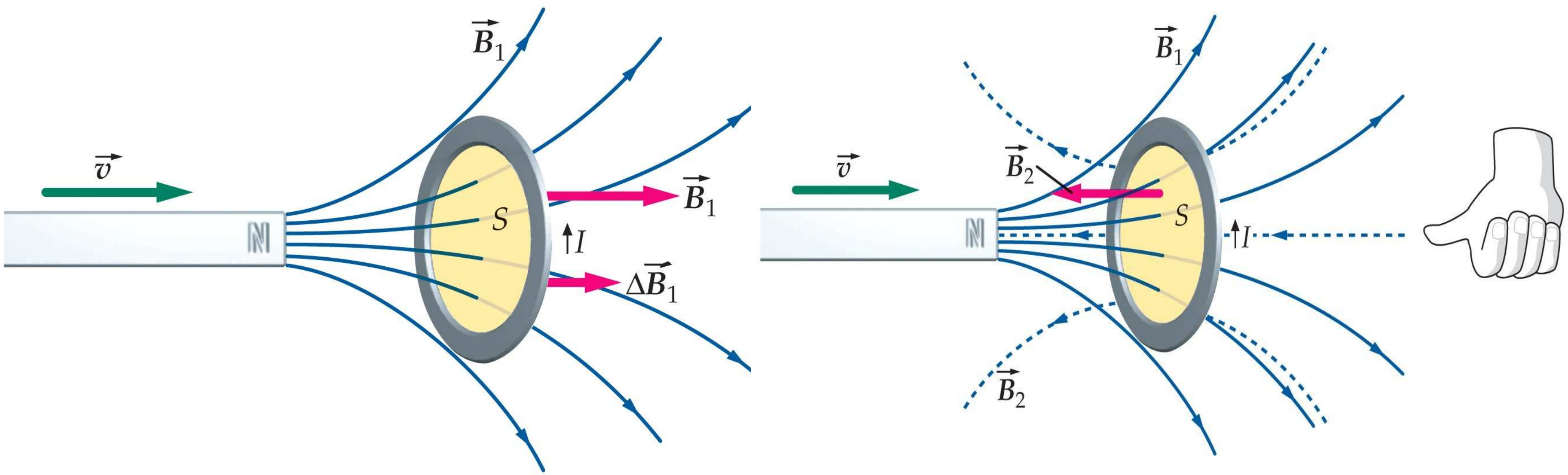
LENZ S LAW



Explicació de la llei de Lenz: $$\mathcal{E} = -\frac{d\phi_m}{dt}$$

When a magnetic flux through a surface changes, the magnetic field due to any induced current produces a flux of its own—through the same surface and in opposition to the change.

ALTERNATIVE STATEMENT OF LENZ'S LAW



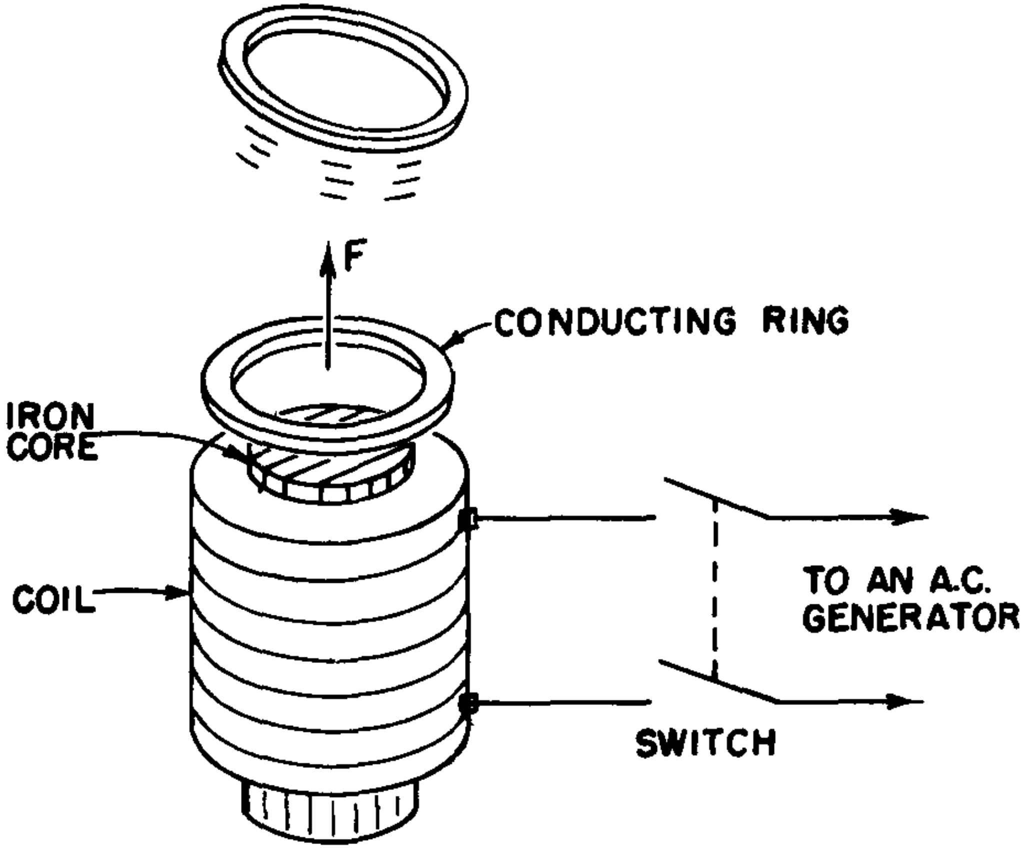
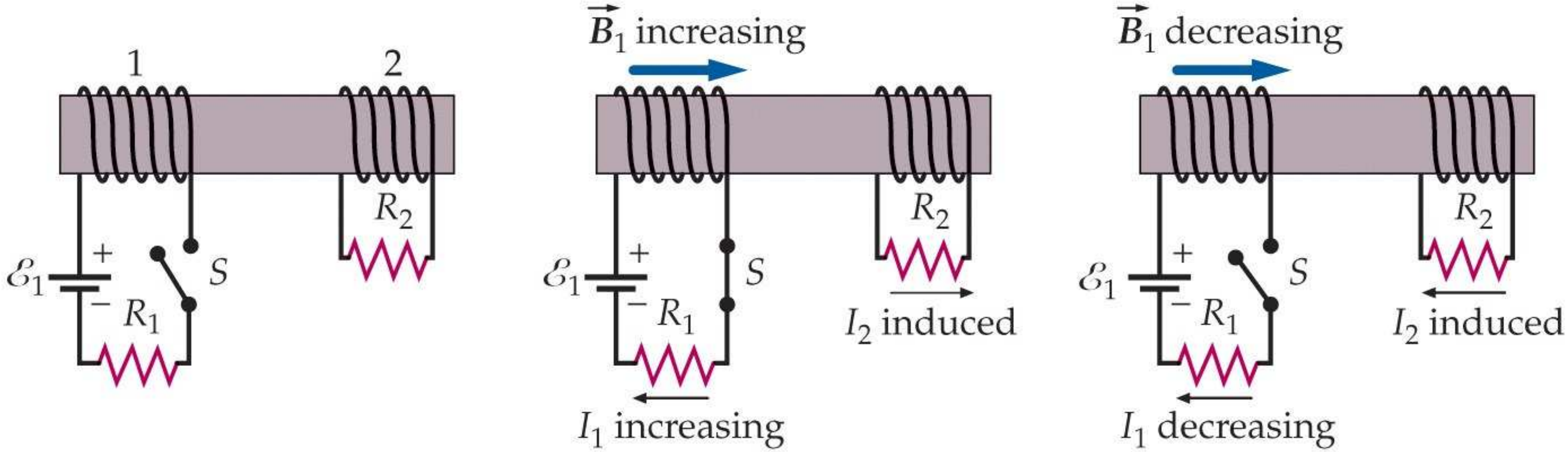


Fig. 16–7. A conducting ring is strongly repelled by an electromagnet with a varying current.

Exemple



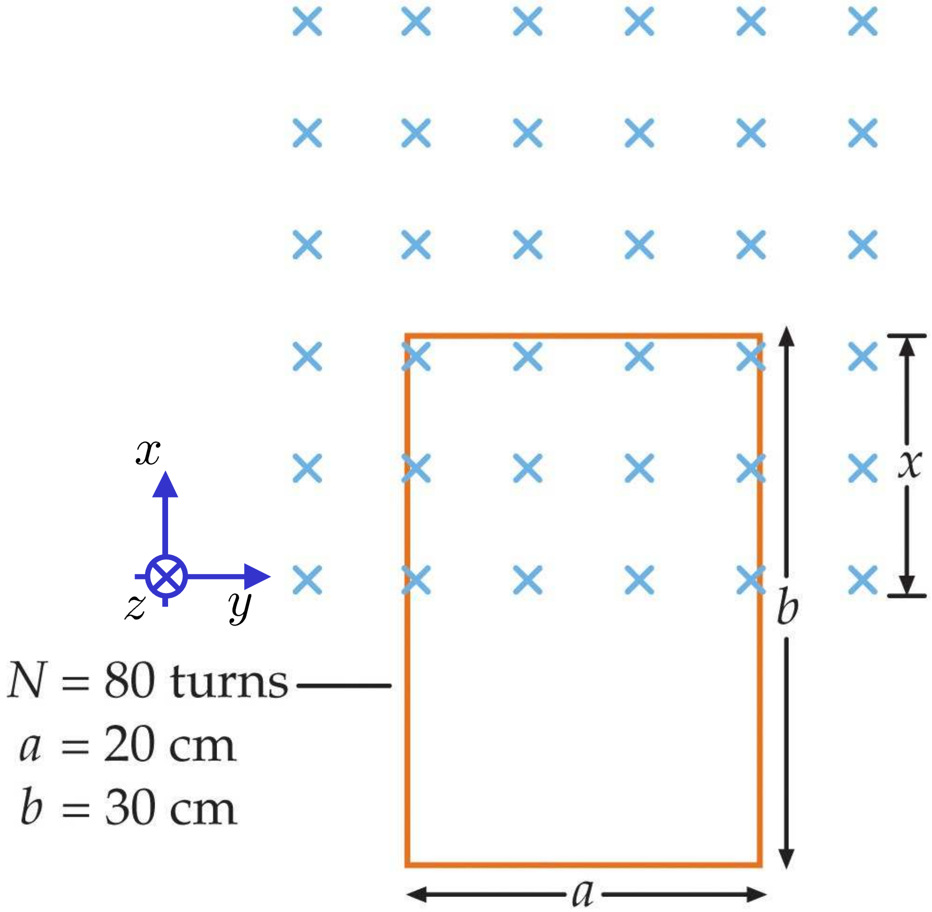
1
2
$\mathcal{E}_1$
+
−
S
R_1
R_2
$\vec{B}_1$ increasing
$\mathcal{E}_1$
+
−
S
R_1
R_2
I_2 induced
I_1 increasing
$\vec{B}_1$ decreasing
$\mathcal{E}_1$
+
−
S
R_1
R_2
I_2 induced
I_1 decreasing

Exemple

$$B = 0.8\ \mathrm{T}$$

$$\vec{v} = 2\ \frac{\mathrm{m}}{\mathrm{s}}\ \hat{u}$$

$$R = 30\ \Omega$$



$$\phi_m = NBax$$

$$\mathcal{E} = -NBa\frac{dx}{dt}$$

$$I = \frac{\mathcal{E}}{R}$$

$\hat{u} = \hat{u}_y \qquad I = 0$

$\hat{u} = \hat{u}_x \qquad I = -0.853\ \mathrm{A}$ (sentit antihorari)

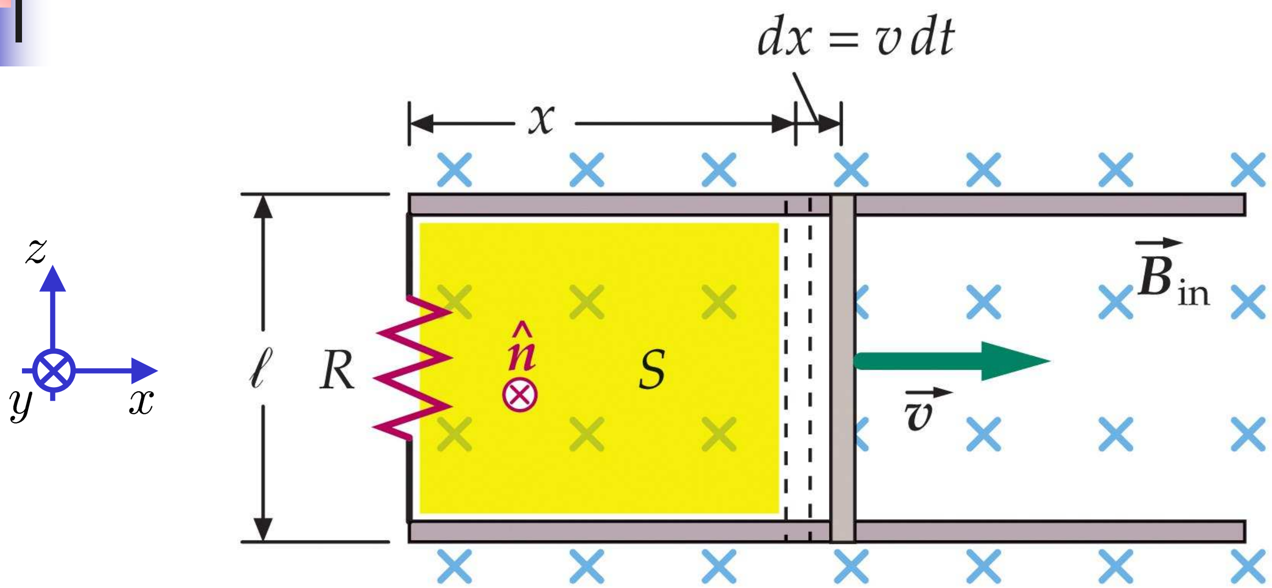
$\hat{u} = -\hat{u}_x \qquad I = 0.853\ \mathrm{A}$ (sentit horari)

Fem de moviment

Motional emf is any emf induced by the motion of a conductor in a magnetic field.

DEFINITION — MOTIONAL EMF

La barra en moviment

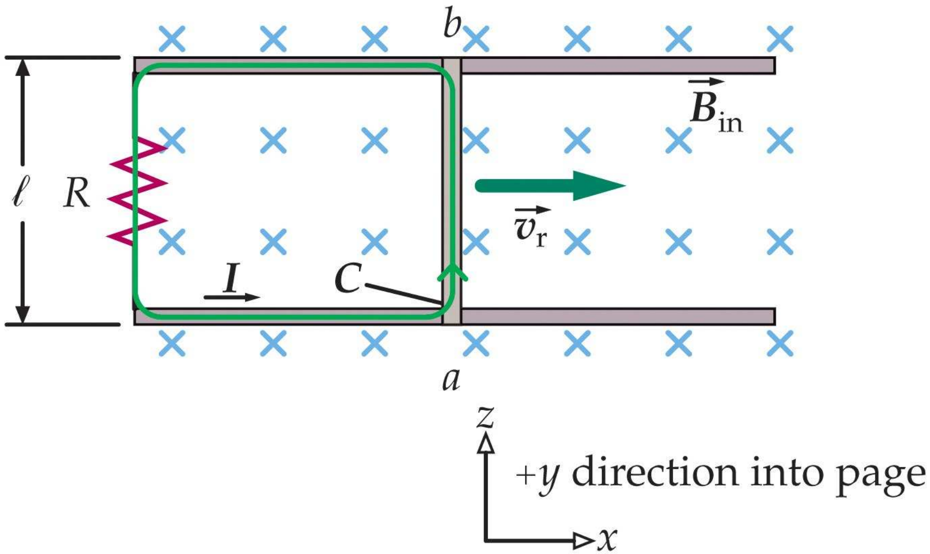


$$\phi_m = B\ell x$$

$$\mathcal{E} = -B\ell v$$

Sentit antihorari

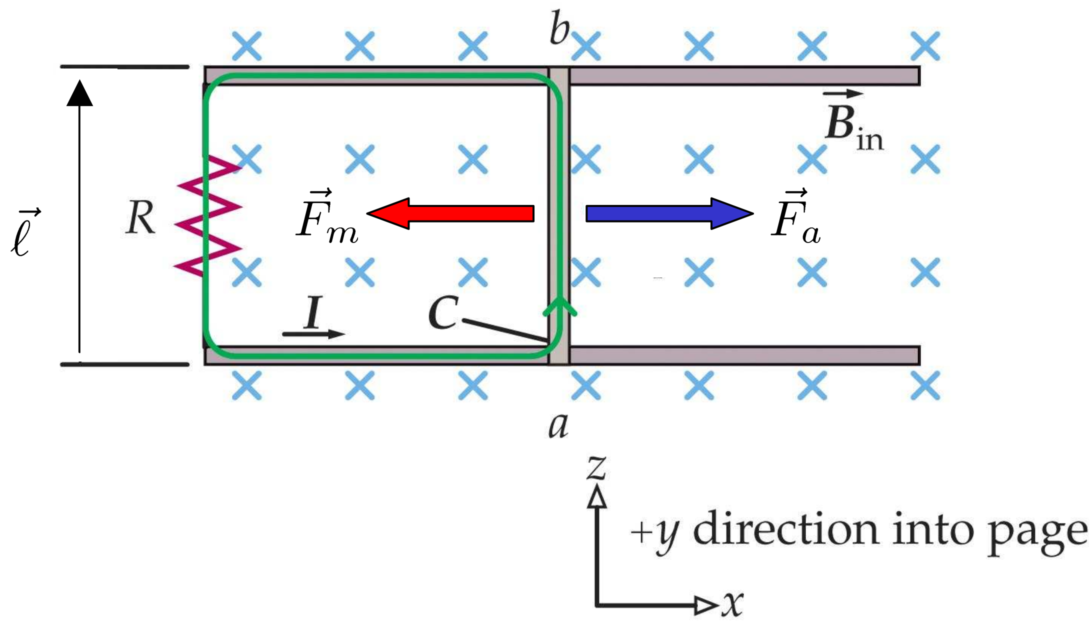
Integrant la força de Lorentz:



$$\vec{F} = qvB\,\hat{u}_z$$

$$\oint_C \frac{\vec{F}}{q} \cdot d\vec{\ell} = vB\ell = |\mathcal{E}|$$

Forces:



$$|\mathcal{E}| = B\ell v$$

$$I = \frac{\mathcal{E}}{R}$$

$$\vec{F}_m = I\vec{\ell} \times \vec{B}$$

$$F_m = I\ell B = \frac{B^2\ell^2}{R}v$$

(fregament proporcional a la velocitat)

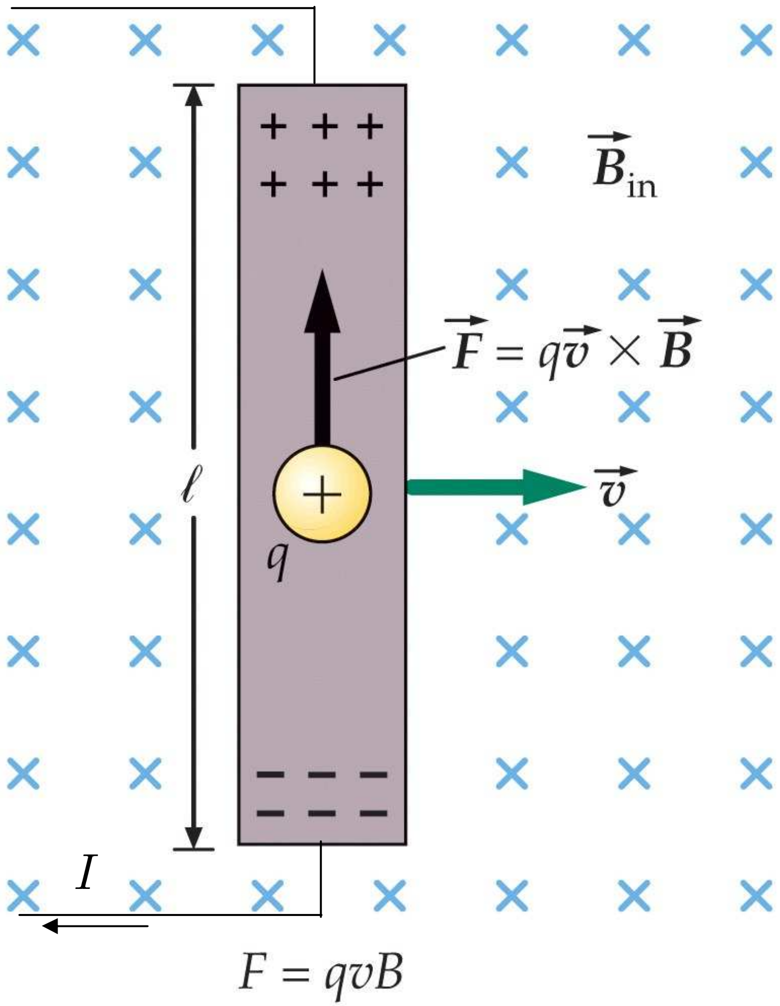
Potència mecànica: $F_a v$

Potència elèctrica: $\mathcal{E}I = \dfrac{B^2\ell^2v^2}{R}$

Transformació d'energia mecánica en energia elèctrica al ritme

$$F_a v = \mathcal{E}I = \frac{B^2\ell^2v^2}{R}$$

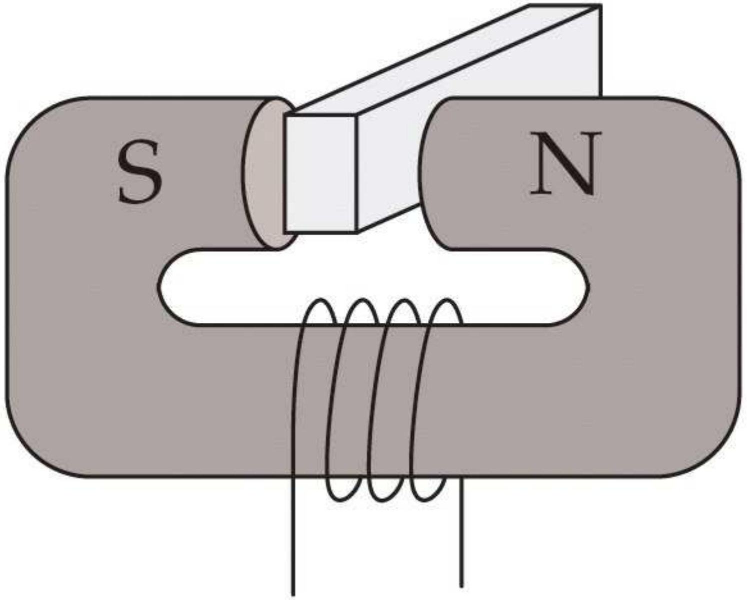
El fre magnètic

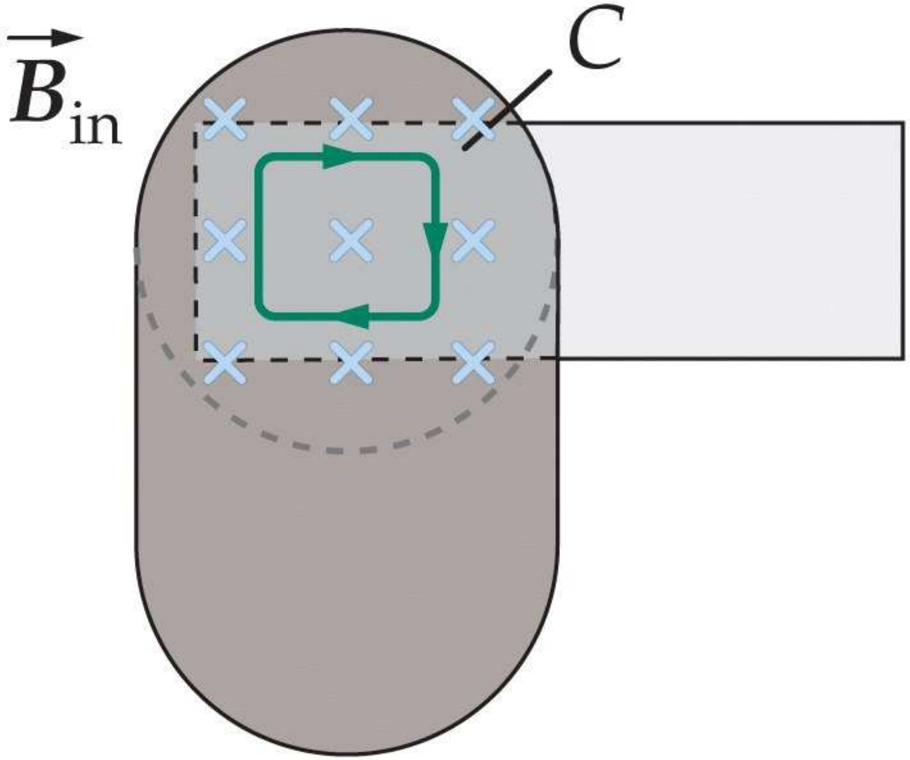


$$\Delta V = vB\ell - Ir \qquad 28\text{-}7$$

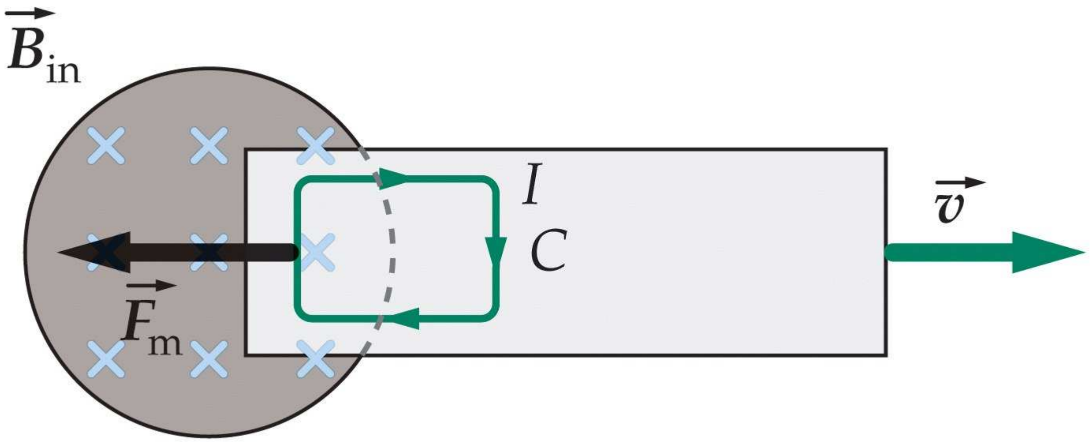
Potential difference across a moving rod

Corrents de Foucault

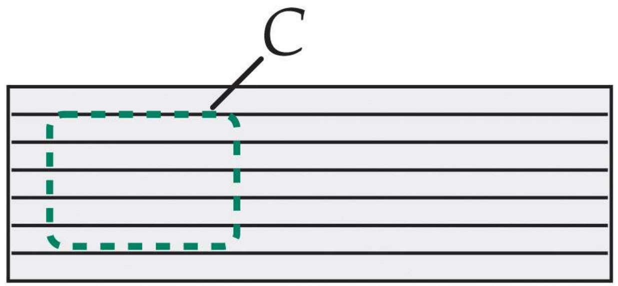


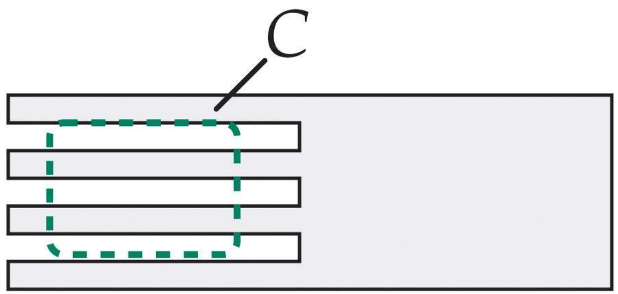


Fre magnètic

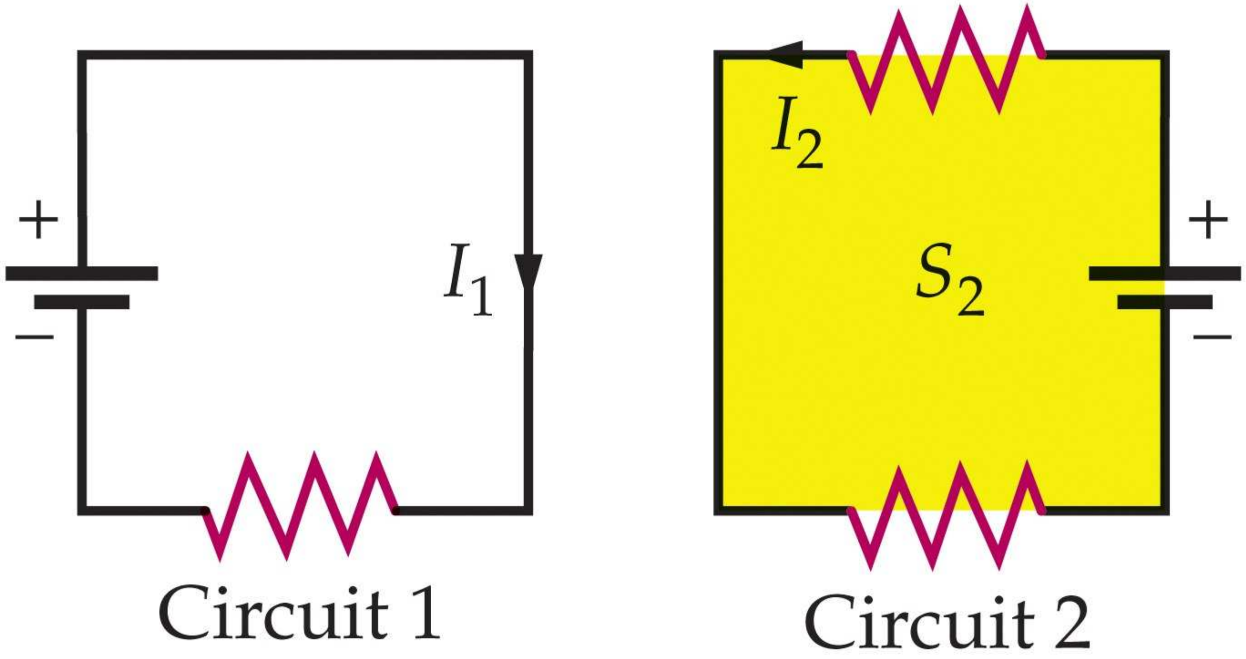


Reducció dels corrents de Foucault





Inductància mútua de dos circuits



$$\phi_{m2,1} = M_{2,1} I_1 \qquad \text{28-14}a$$

DEFINITION—MUTUAL INDUCTANCE

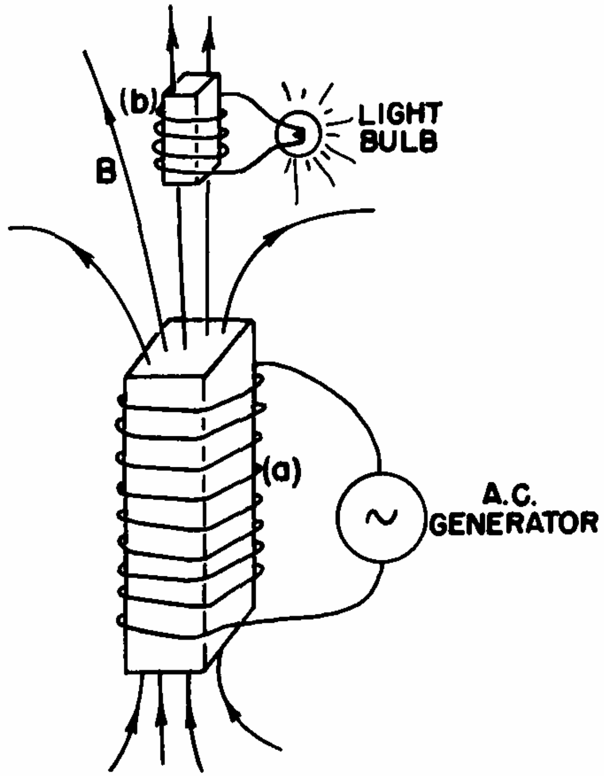
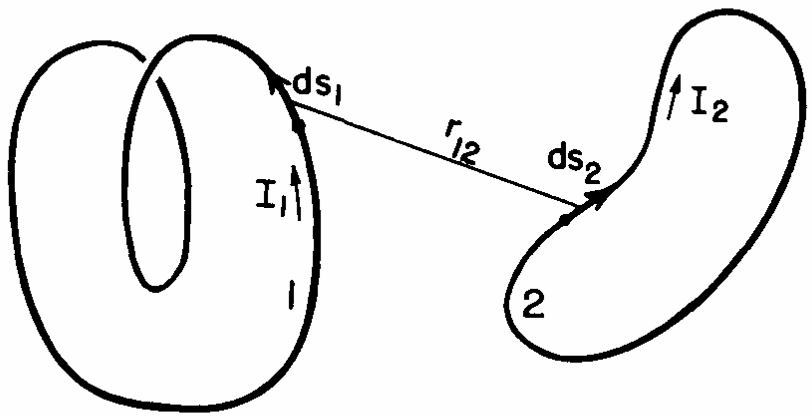


Fig. 16–5. Two coils, wrapped around bundles of iron sheets, allow a generator to light a bulb with no direct connection.

Fig. 17–9. Any two coils have a mutual inductance $\mathfrak{M}$ proportional to the integral of $ds_1 \cdot ds_2/r_{12}$.



Dues bobines coaxials

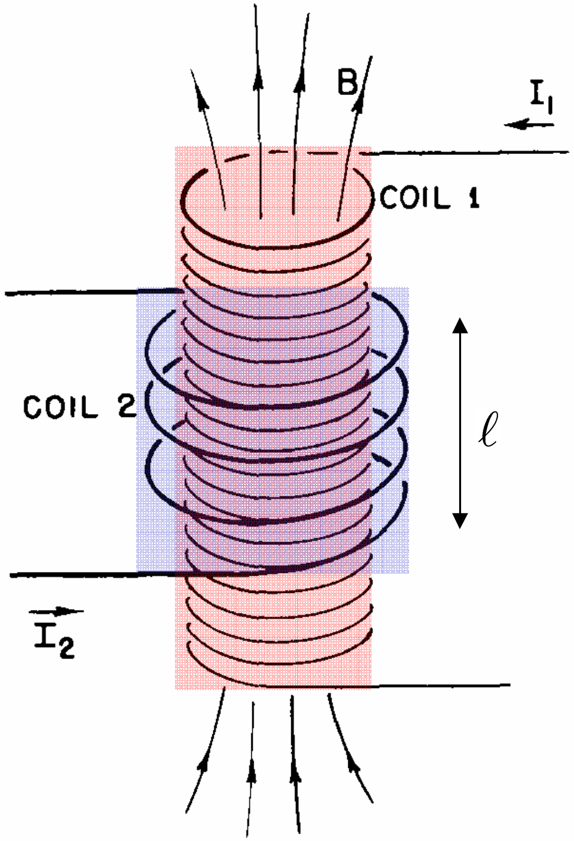


Fig. 17–8. A current in coil 1 produces a magnetic field through coil 2.

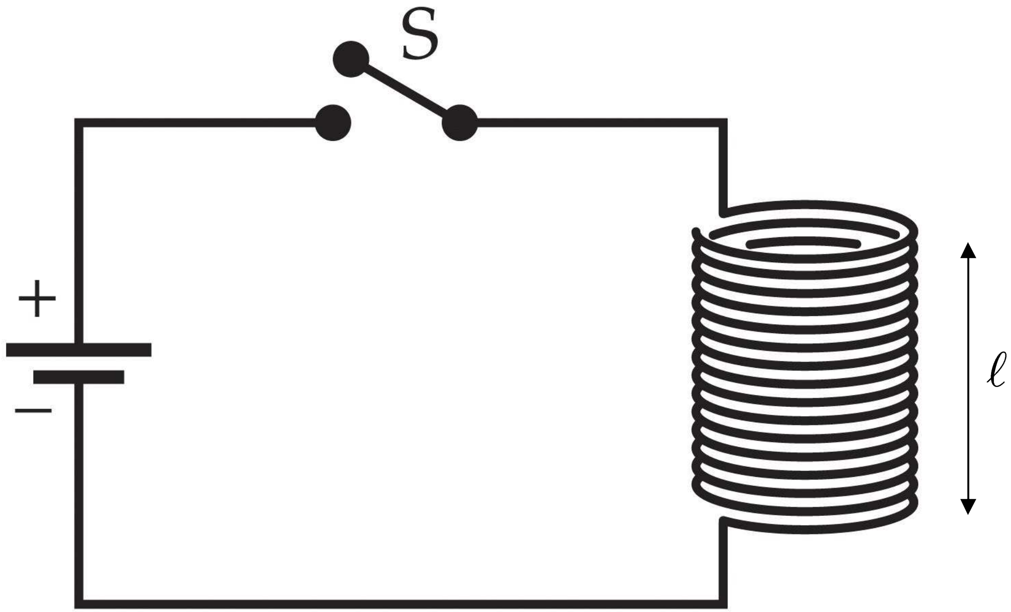
$$B_1 = \mu_0 n_1 I_1$$

$$\phi_{m2} = N_2 B_1 \left(\pi r_1^2\right) = \mu_0 n_1 n_2 \ell \left(\pi r_1^2\right) I_1$$

$$\boxed{M_{21} = \mu_0 n_1 n_2 \ell \left(\pi r_1^2\right)}$$

$$M_{12} = M_{21}$$

Autoinducció



$$\phi_m = LI$$

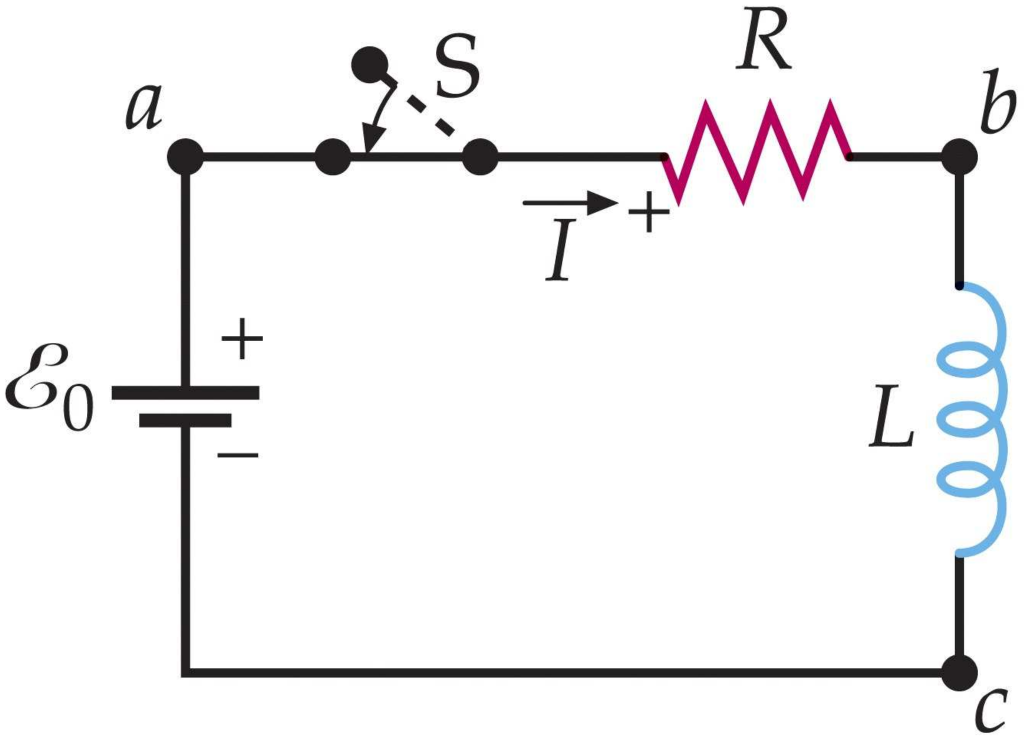
$$L = \mu_0 n^2 A\ell$$

$$\boxed{\mathcal{E} = -L\frac{dI}{dt}}$$

unitats

$$[L] = \frac{1\,\mathrm{Wb}}{1\,\mathrm{A}} = 1\,\frac{\mathrm{Tm}^2}{\mathrm{A}} = 1\,\mathrm{H}$$ henri

Energia magnètica



$$\mathcal{E}_0 - IR - L\frac{dI}{dt} = 0$$

$$\mathcal{E}_0 I = I^2 R + LI\frac{dI}{dt}$$

$$\frac{dU_m}{dt} = LI\frac{dI}{dt}$$

$$\boxed{U_m = \frac{1}{2}LI^2}$$

Intensitat final

Energia emmagatzemada a la bobina

Densitat d'energia del camp magnètic

$$\boxed{u_m = \frac{B^2}{2\mu_0}}$$

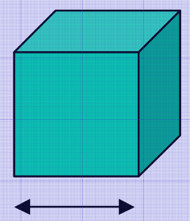
bobina $U_m = u_m V = \frac{B^2}{2\mu_0} A\ell = \frac{1}{2} L I^2$

Camp electromagnètic $u_{em} = u_e + u_m = \frac{1}{2}\epsilon_0 E^2 + \frac{B^2}{2\mu_0}$

Exemple:

$B = 0.020T$

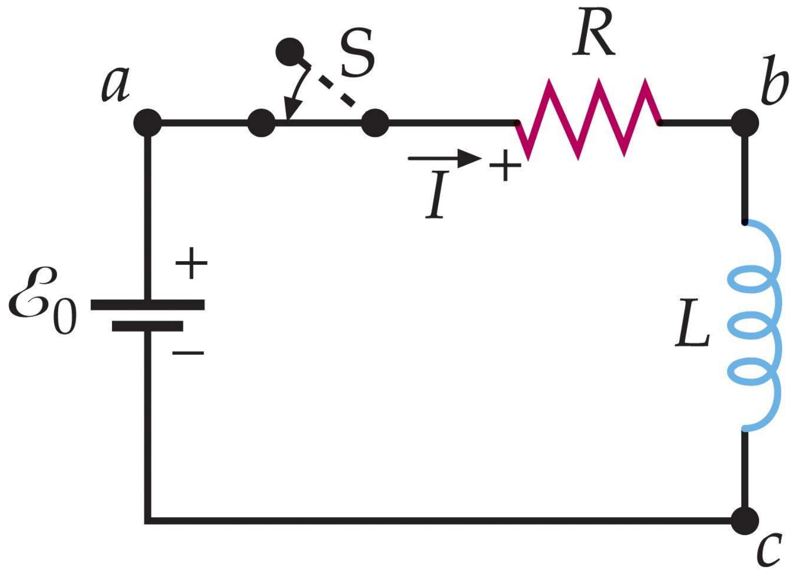
$E = 2.5\,10^6\,\frac{\mathrm{N}}{\mathrm{C}}$



$\ell = 12\,\mathrm{cm}$

$U = u_{em} V = 0.323\,\mathrm{J}$

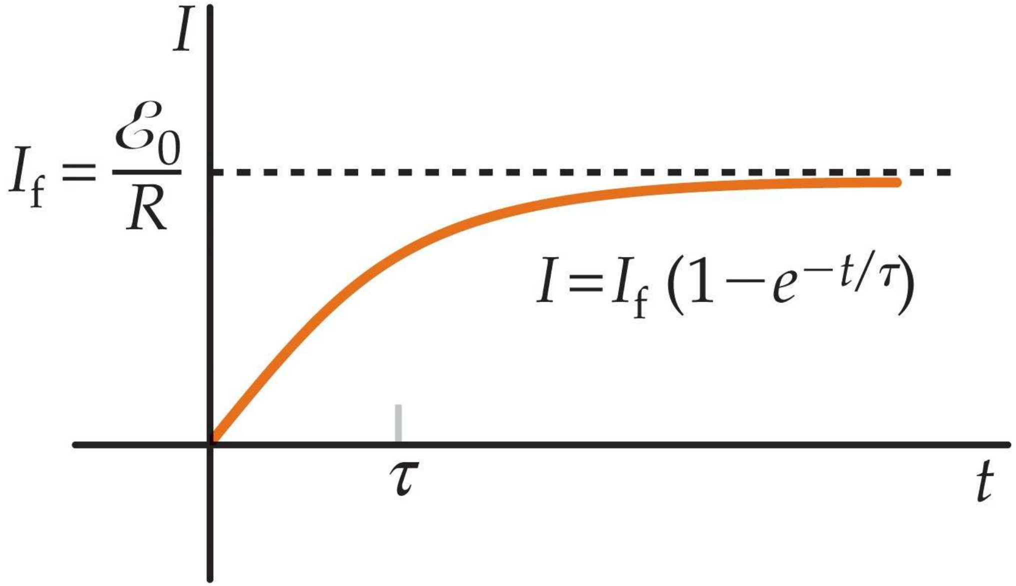
Circuit RL



$$\mathcal{E}_0 - IR - L\frac{dI}{dt} = 0$$

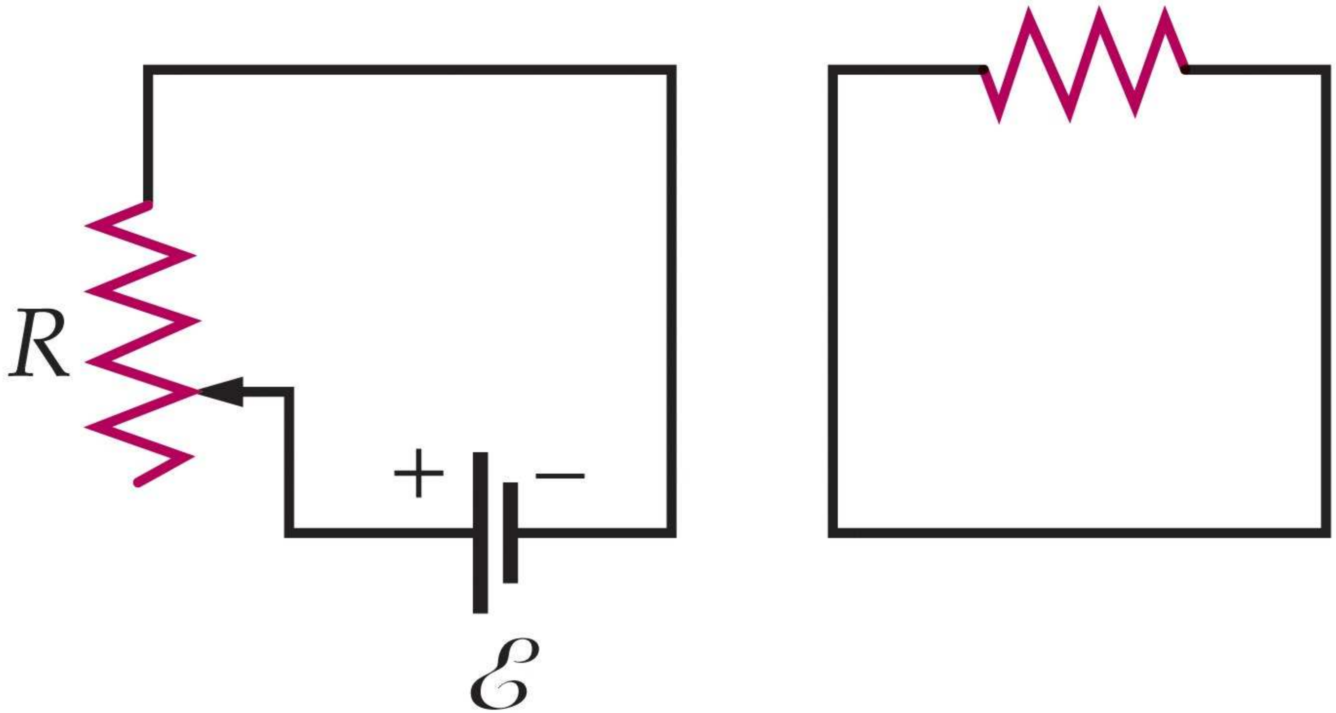
$$\left.\frac{dI}{dt}\right|_{t=0} = \frac{\mathcal{E}_0}{L}\,, \qquad I_f = \frac{\mathcal{E}_0}{R}$$

$$I(t) = \frac{\mathcal{E}_0}{R}\left(1 - e^{-(R/L)t}\right) = I_f\left(1 - e^{-t/\tau}\right)$$

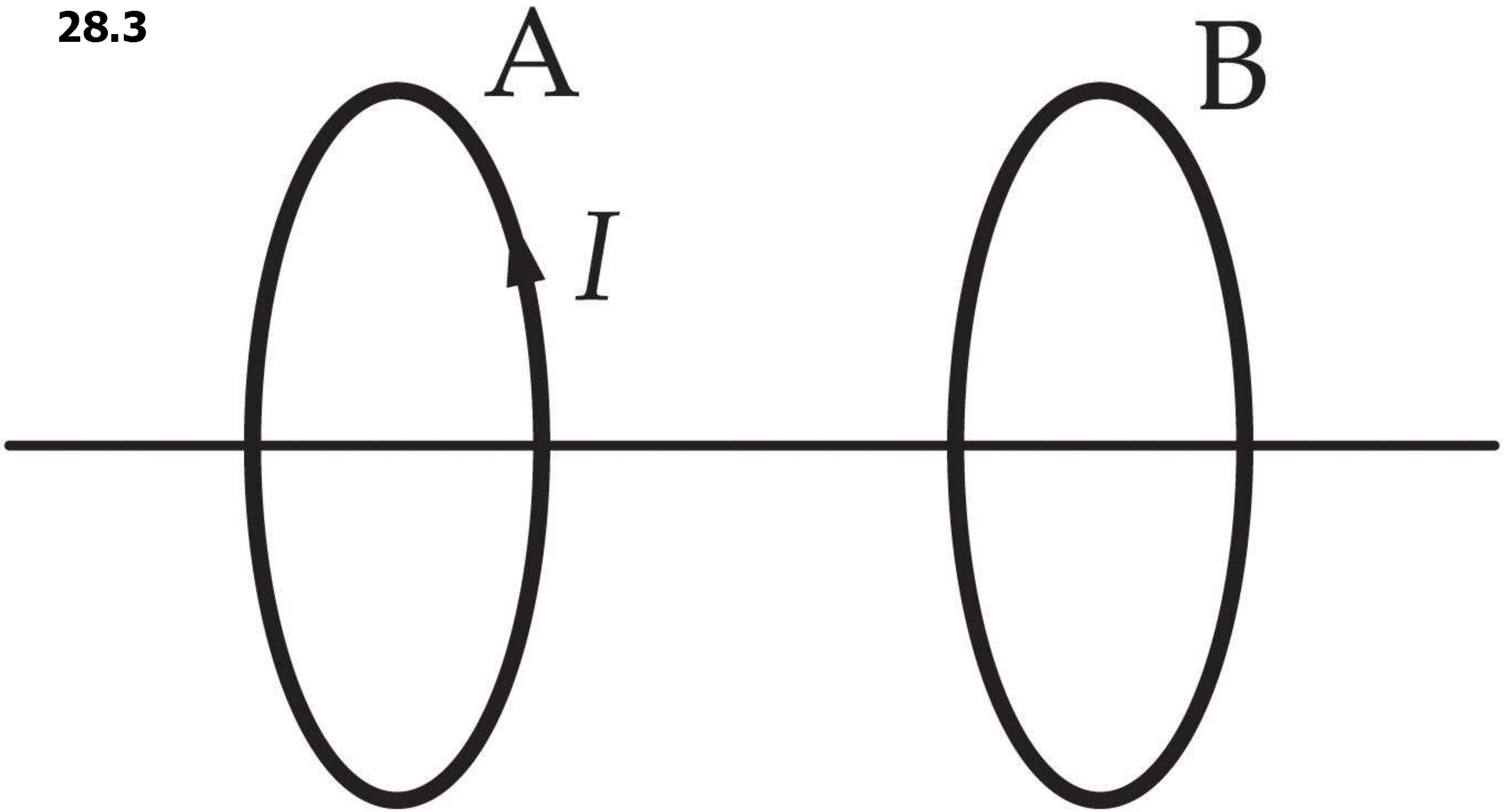


Problems

28.2



28.3



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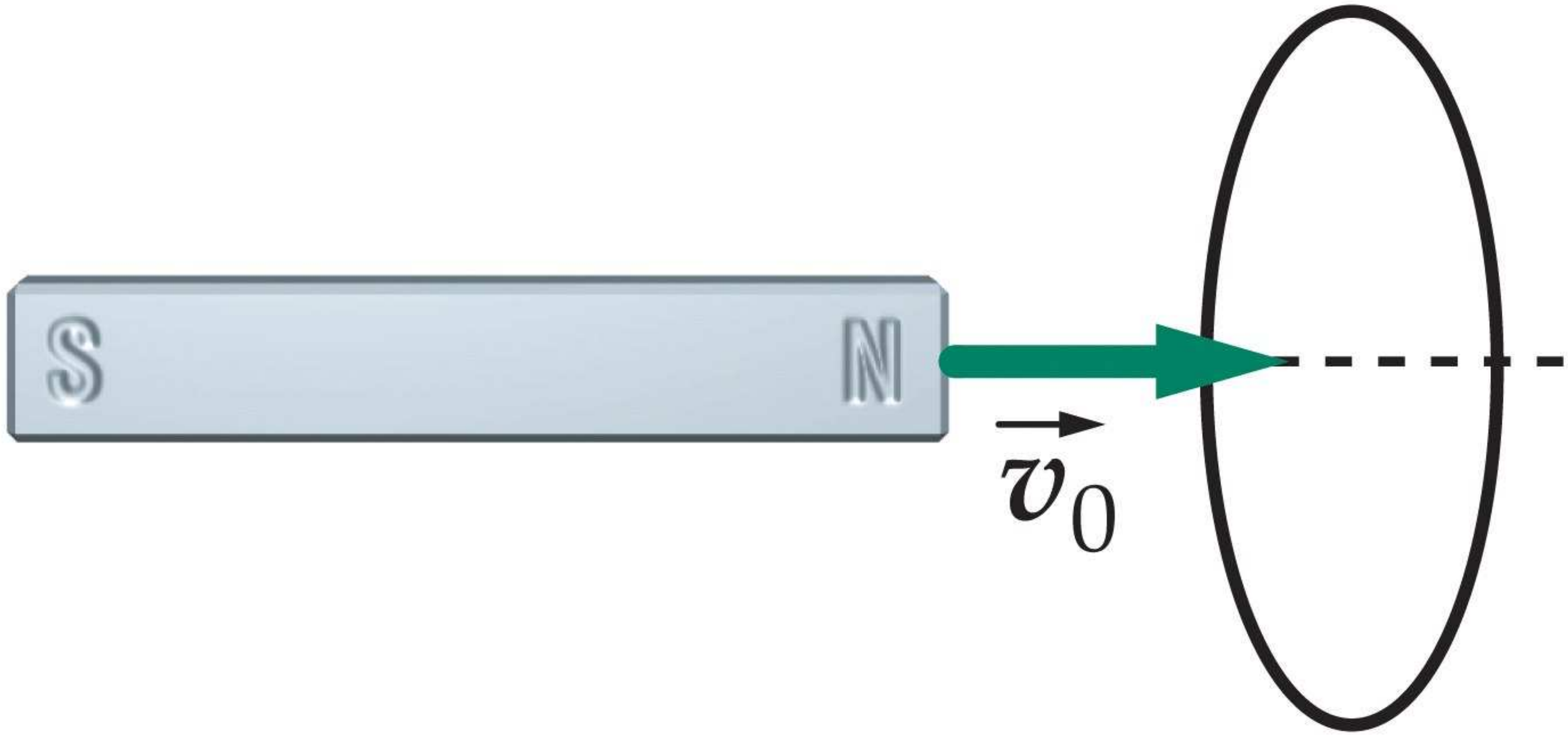
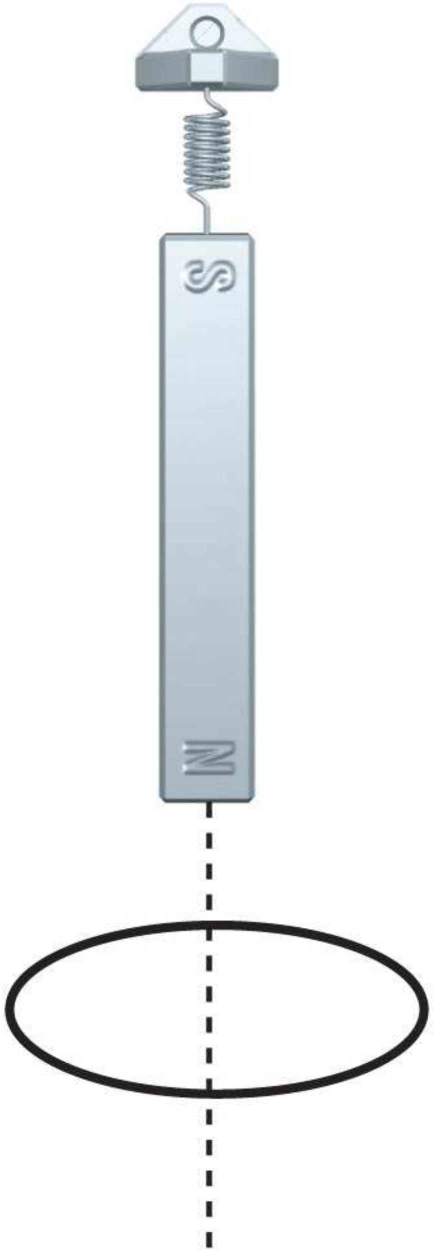
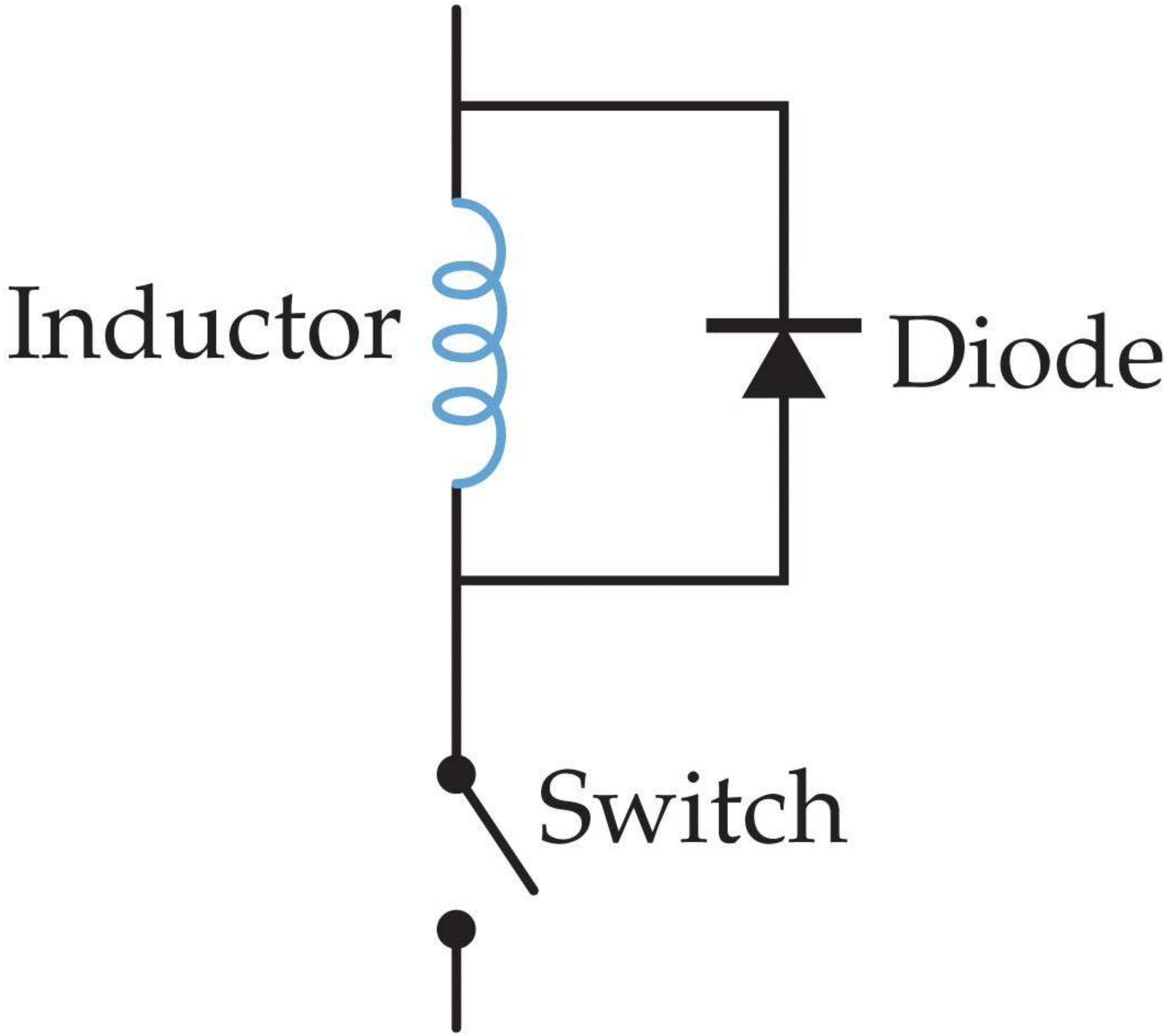


28.5



28.7



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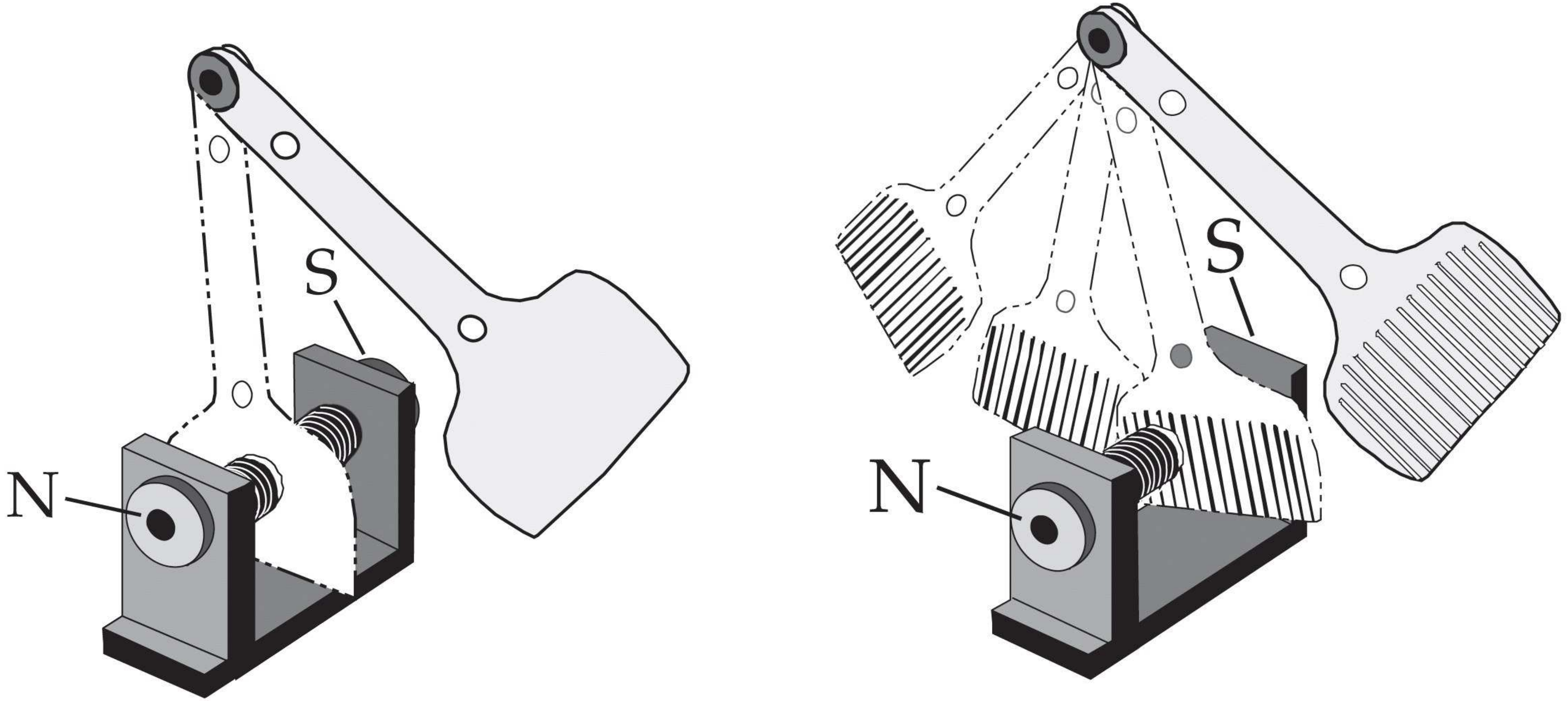

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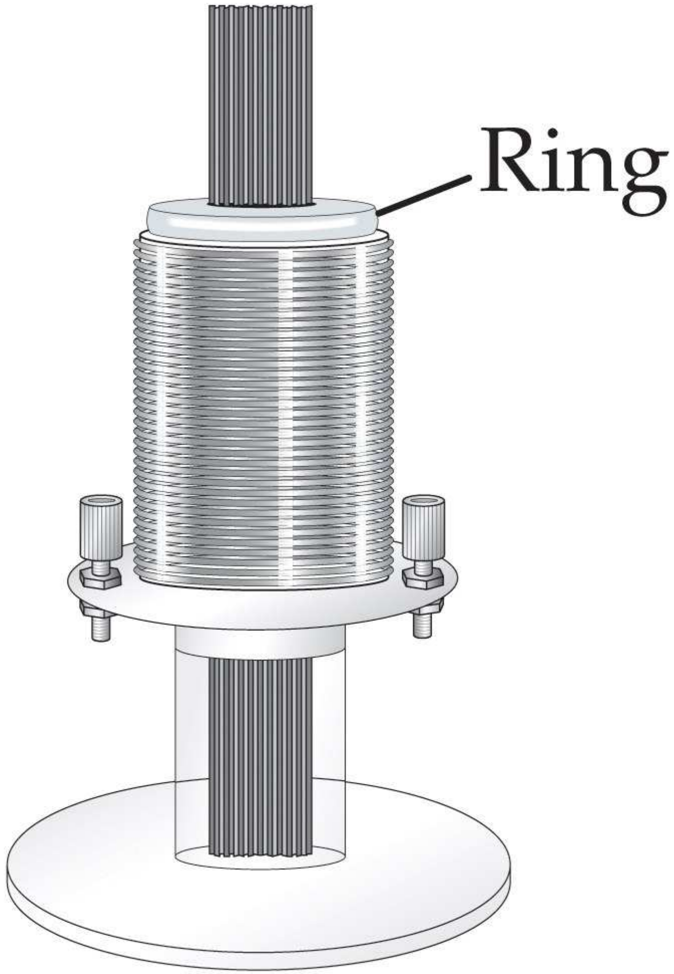

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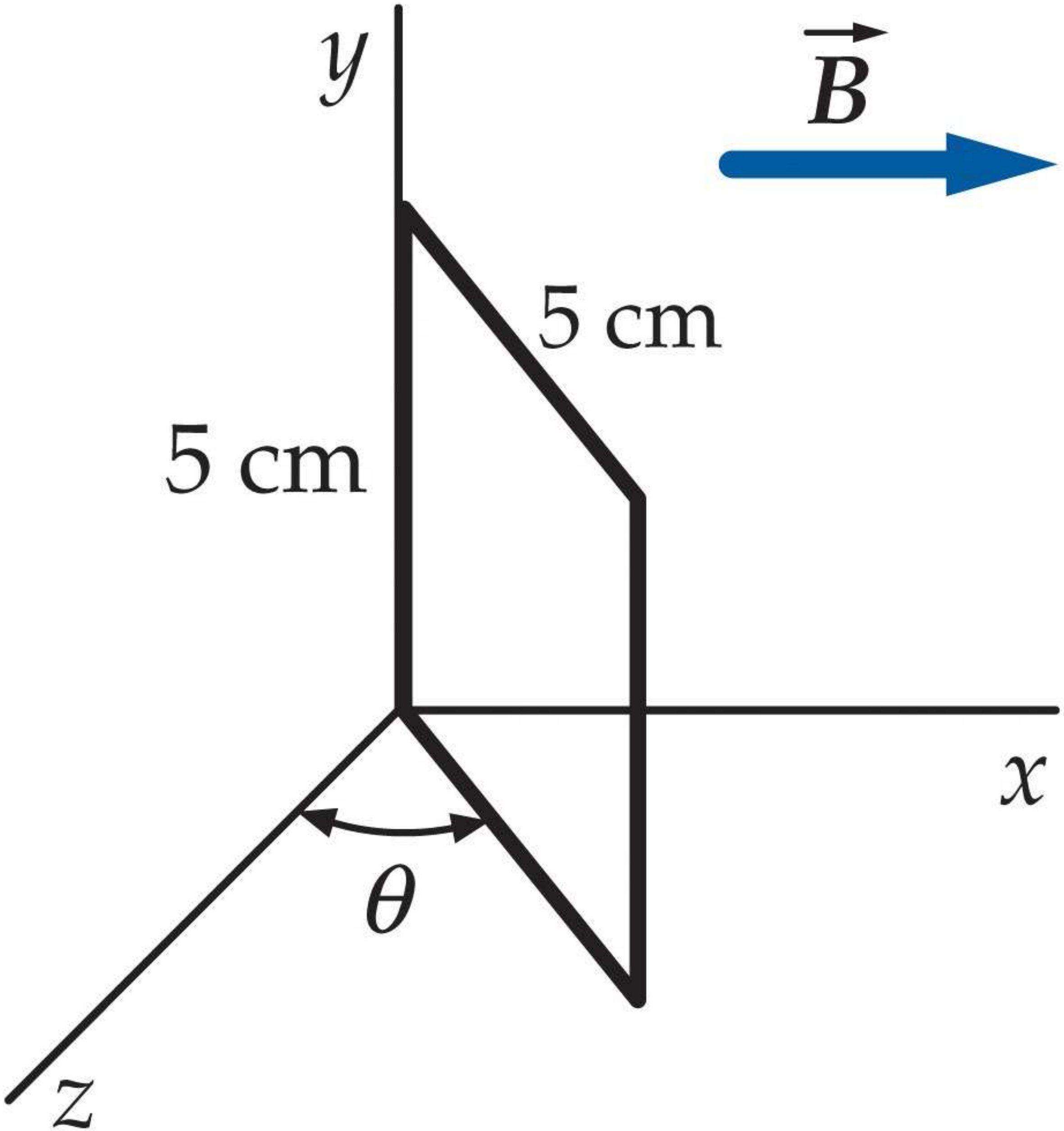

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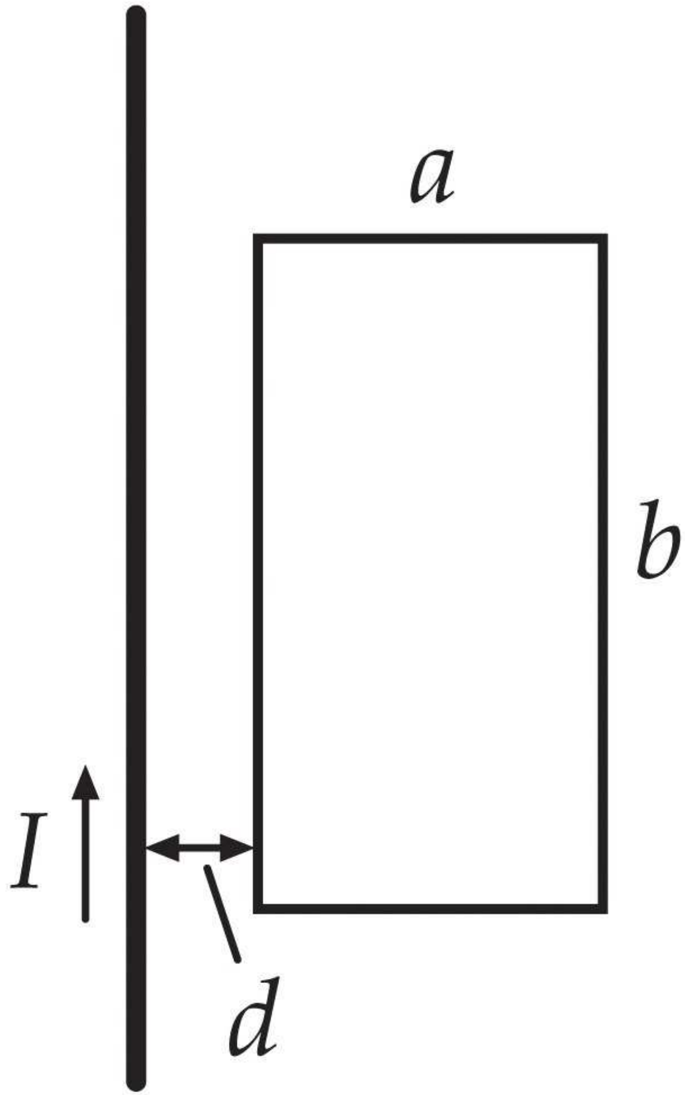

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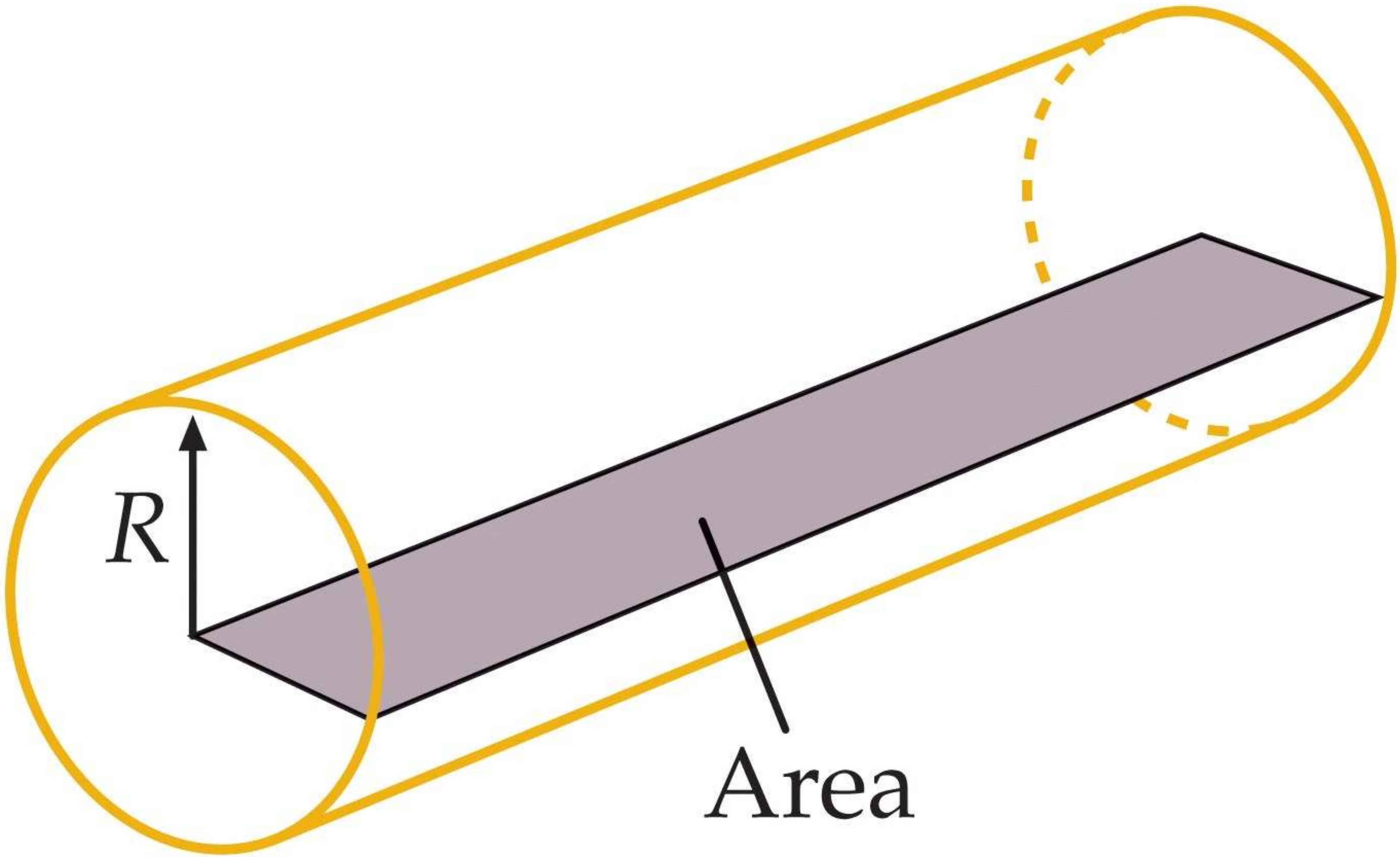

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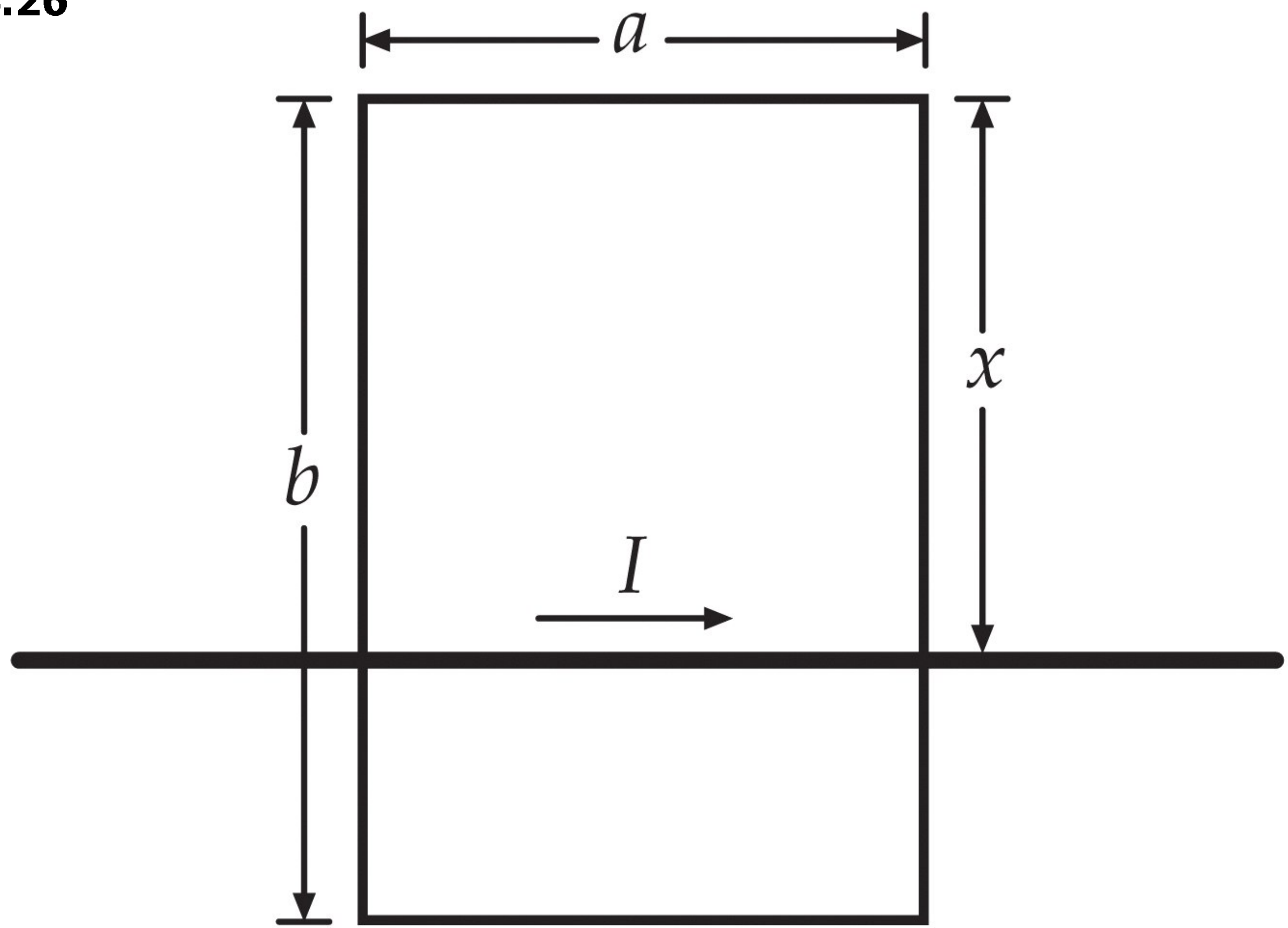

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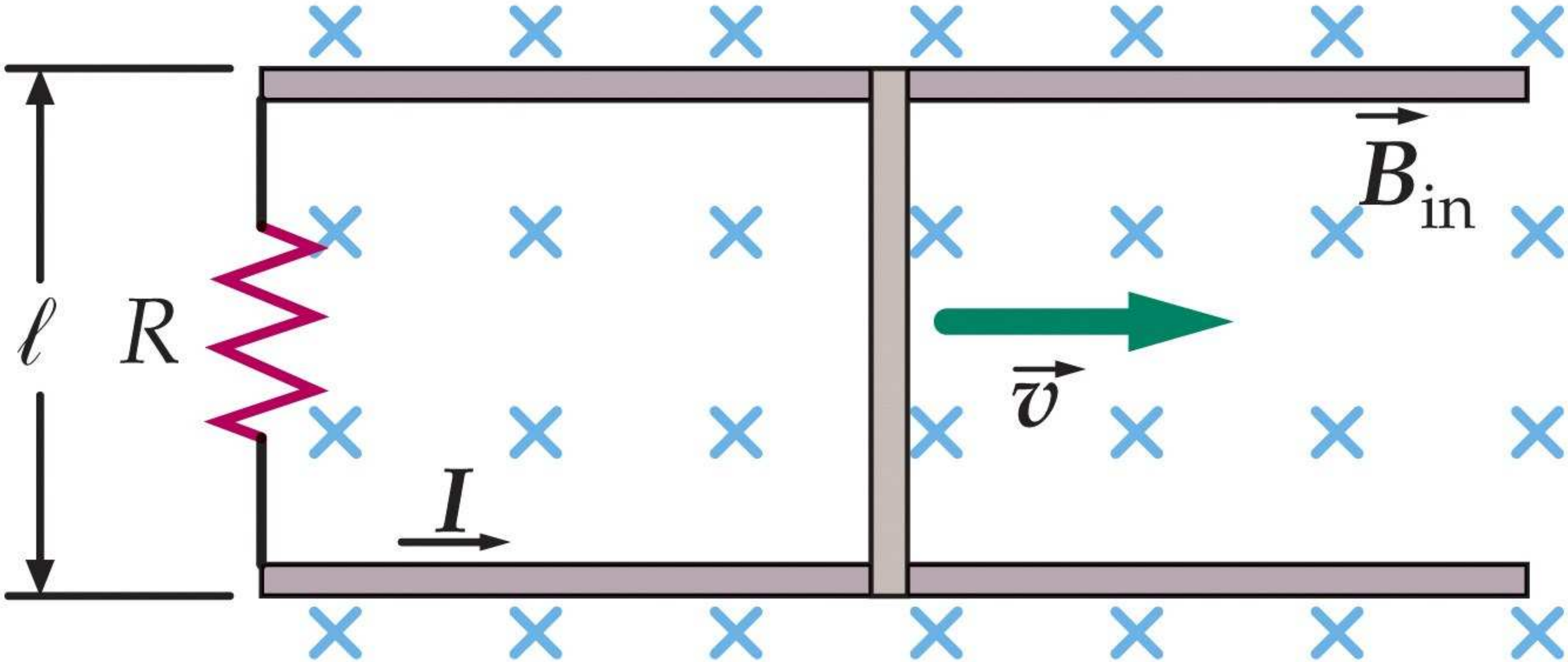

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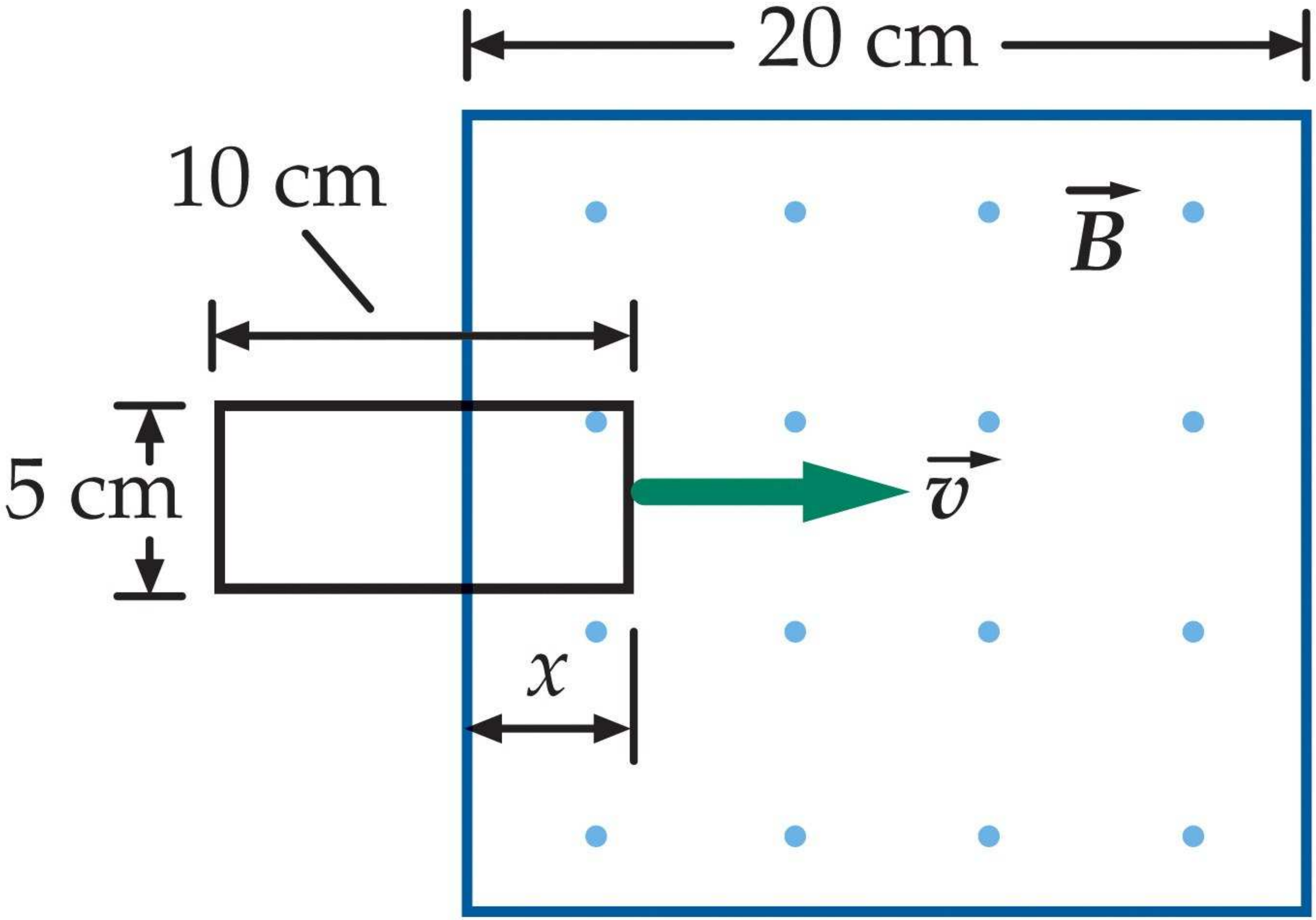

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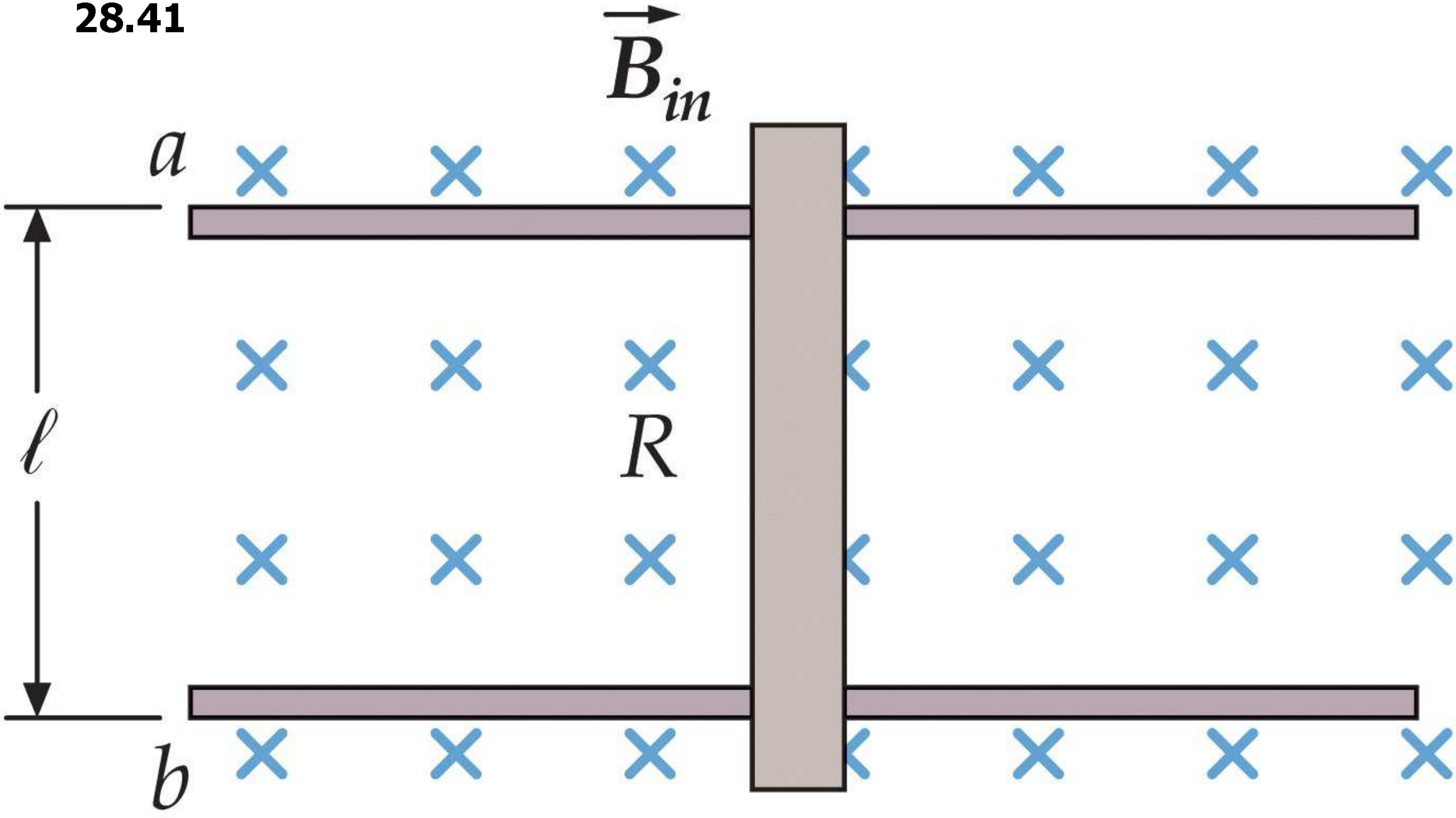

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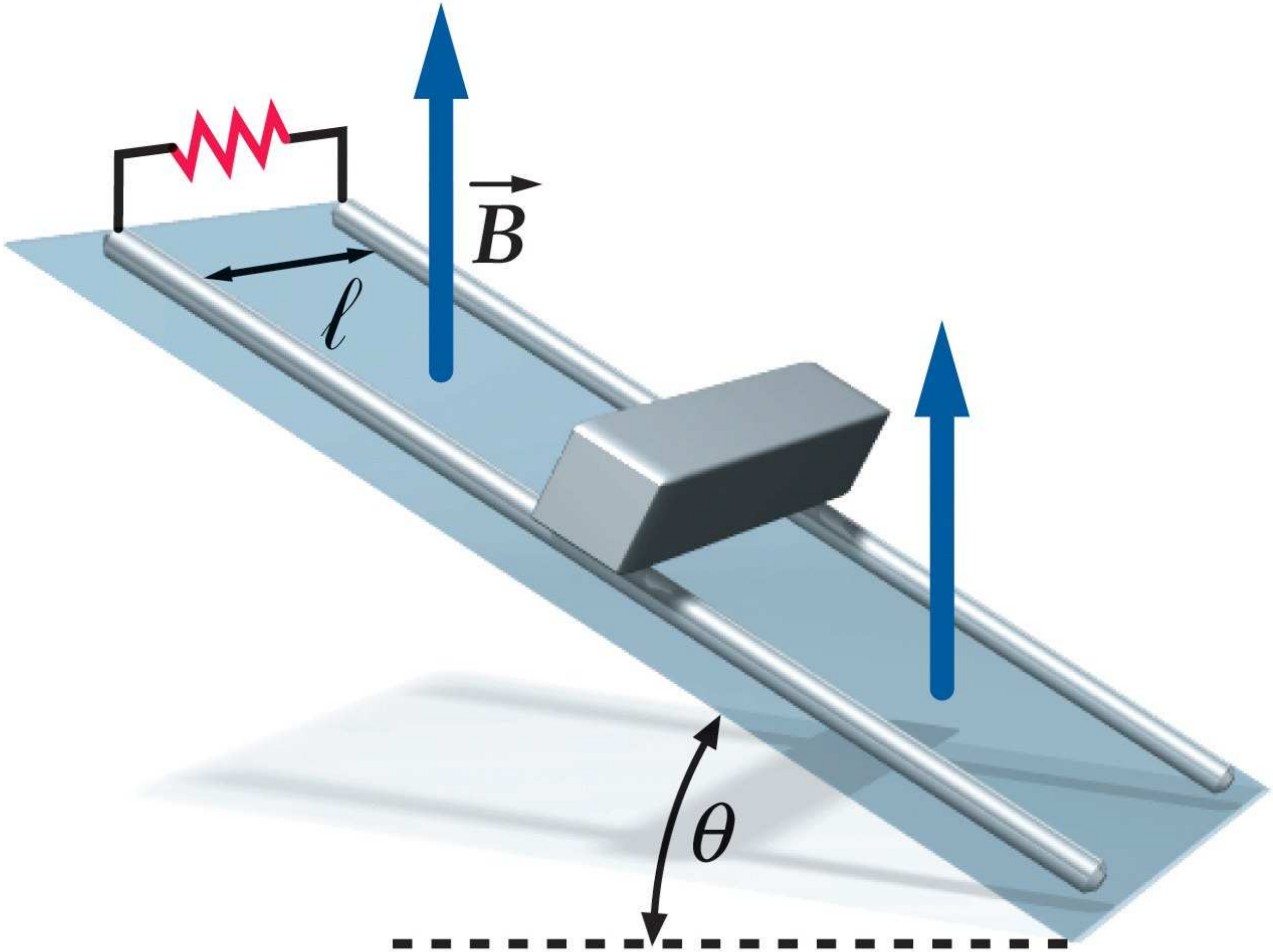

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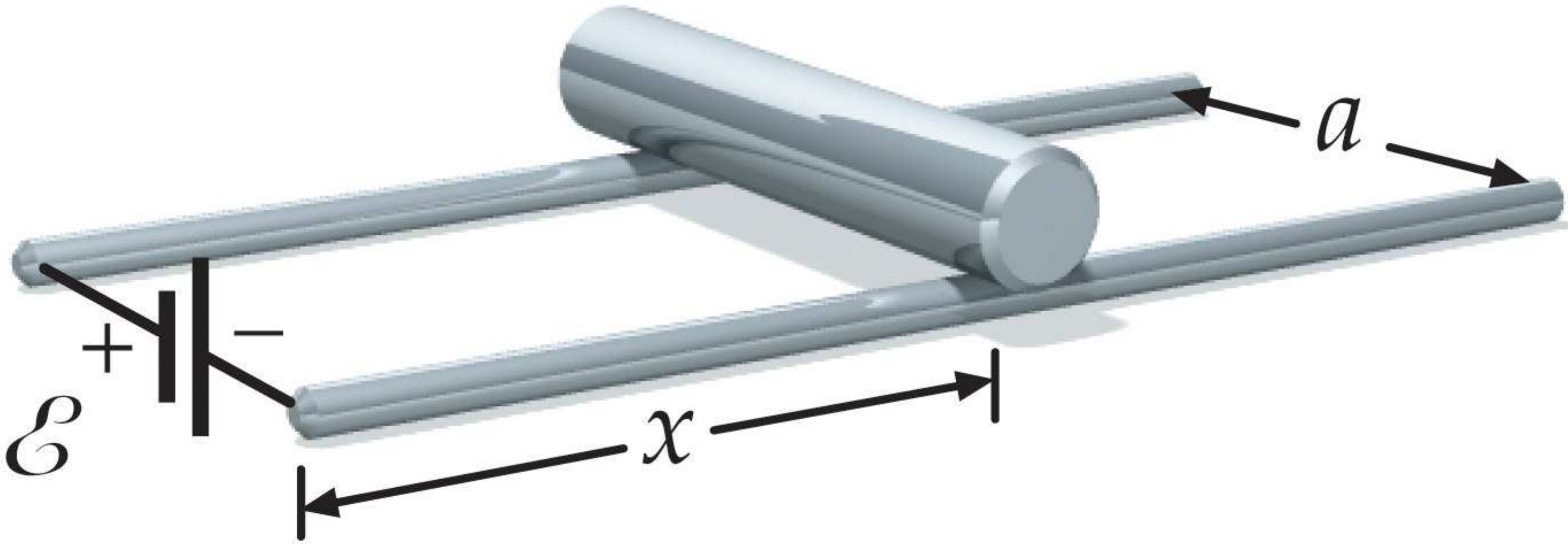

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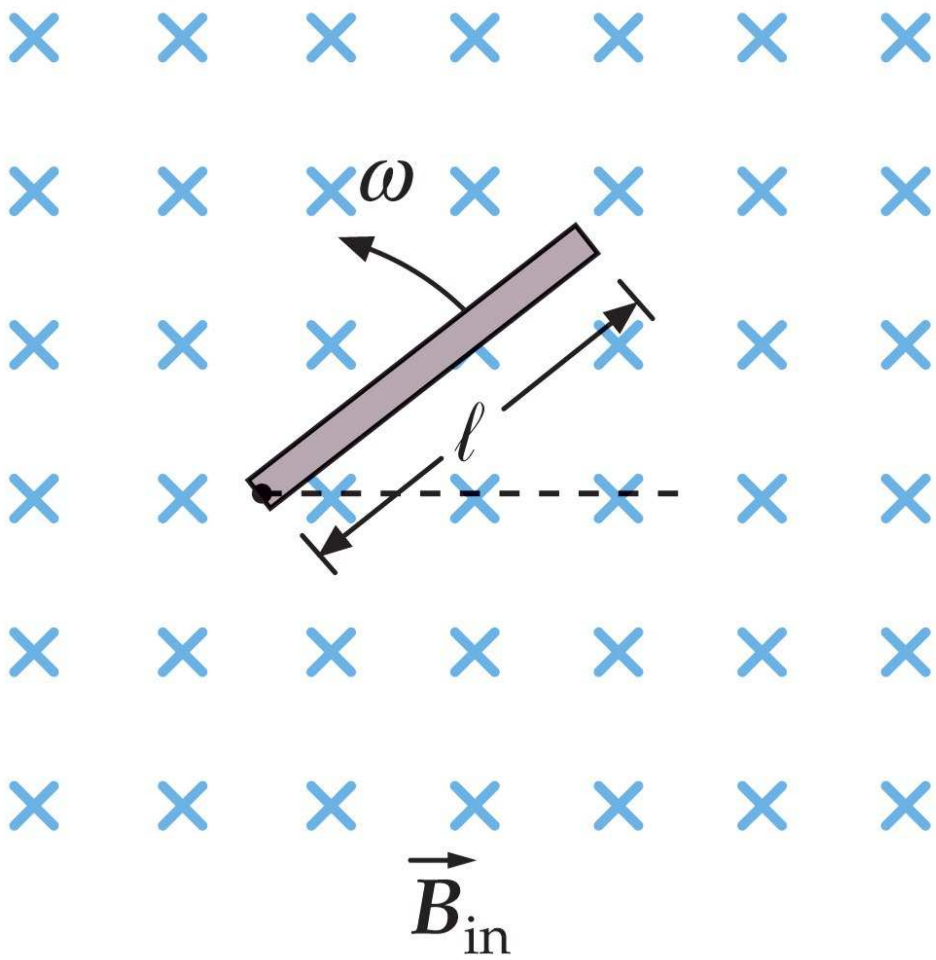

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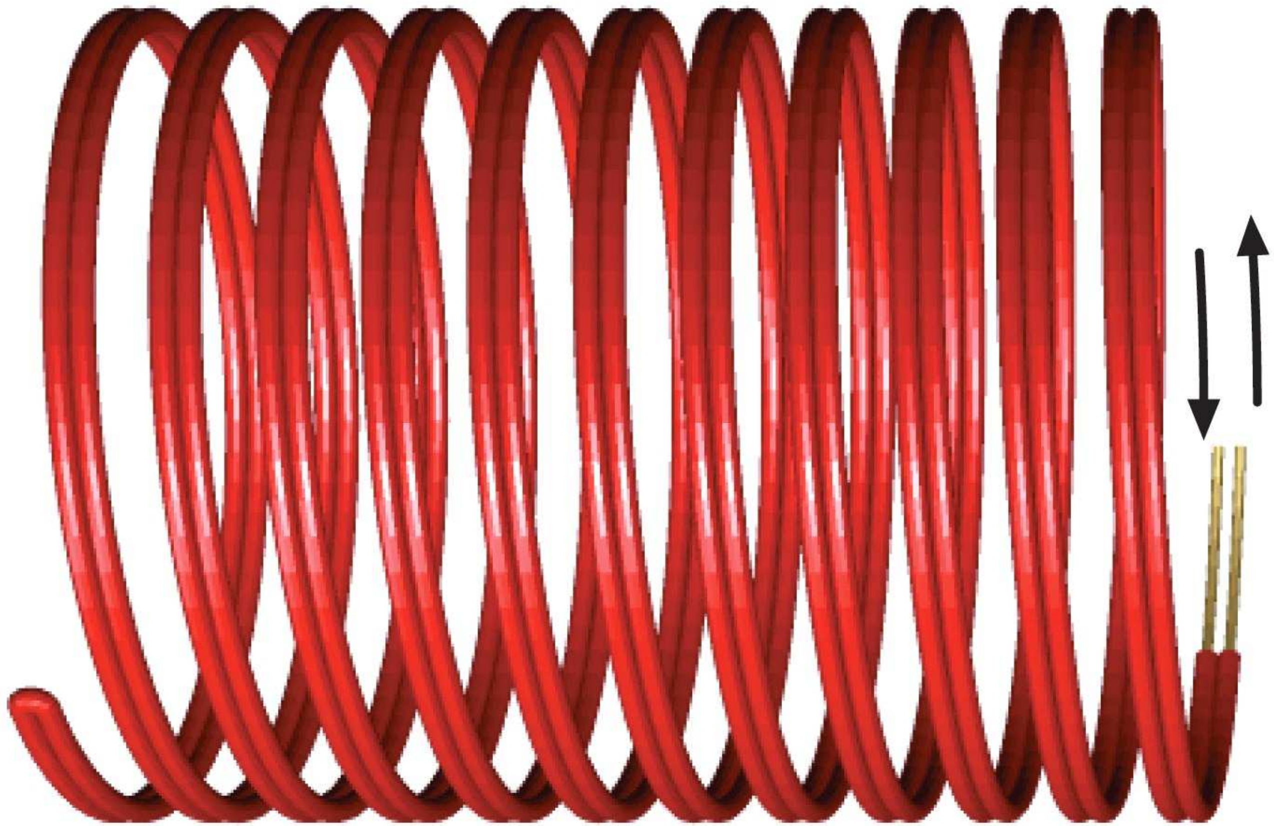

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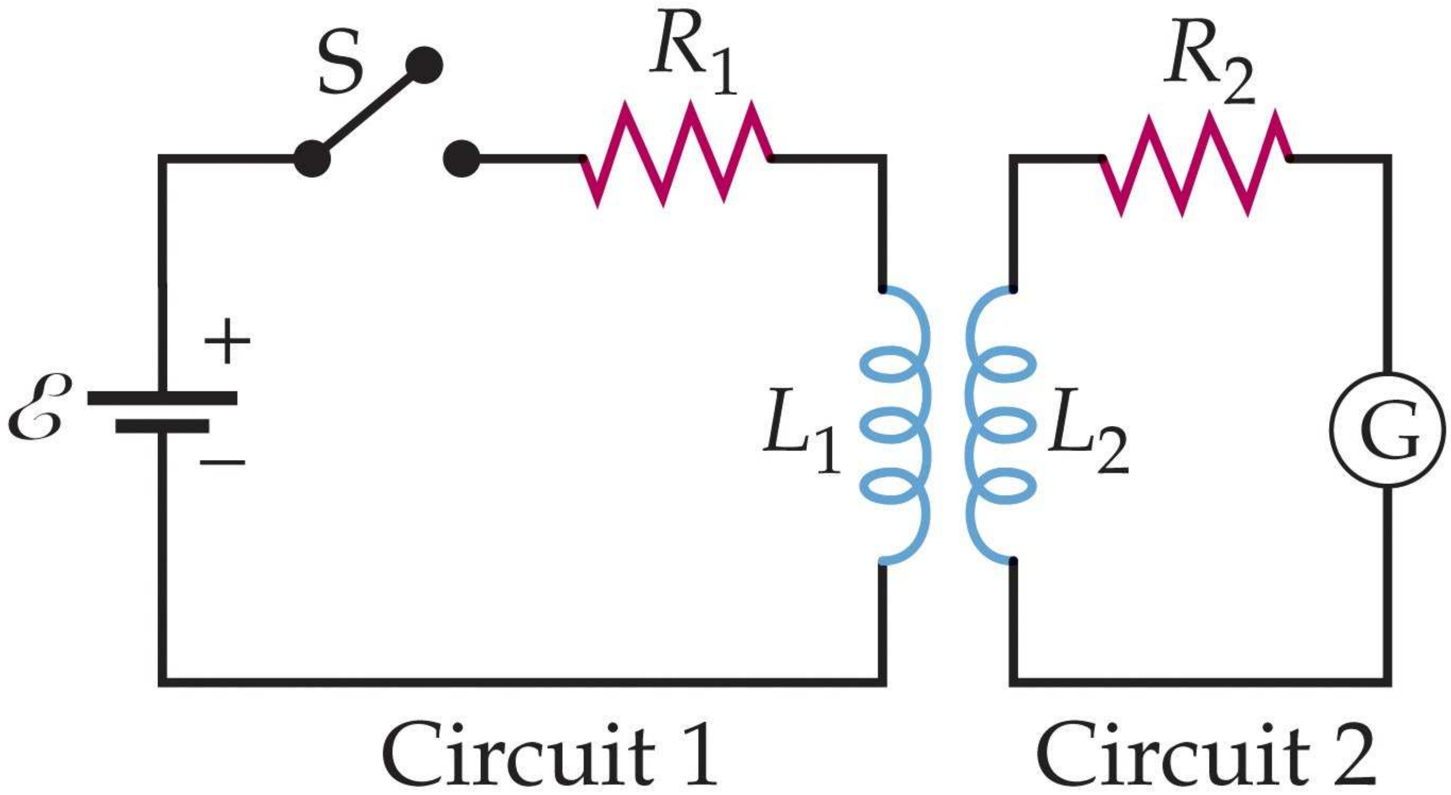

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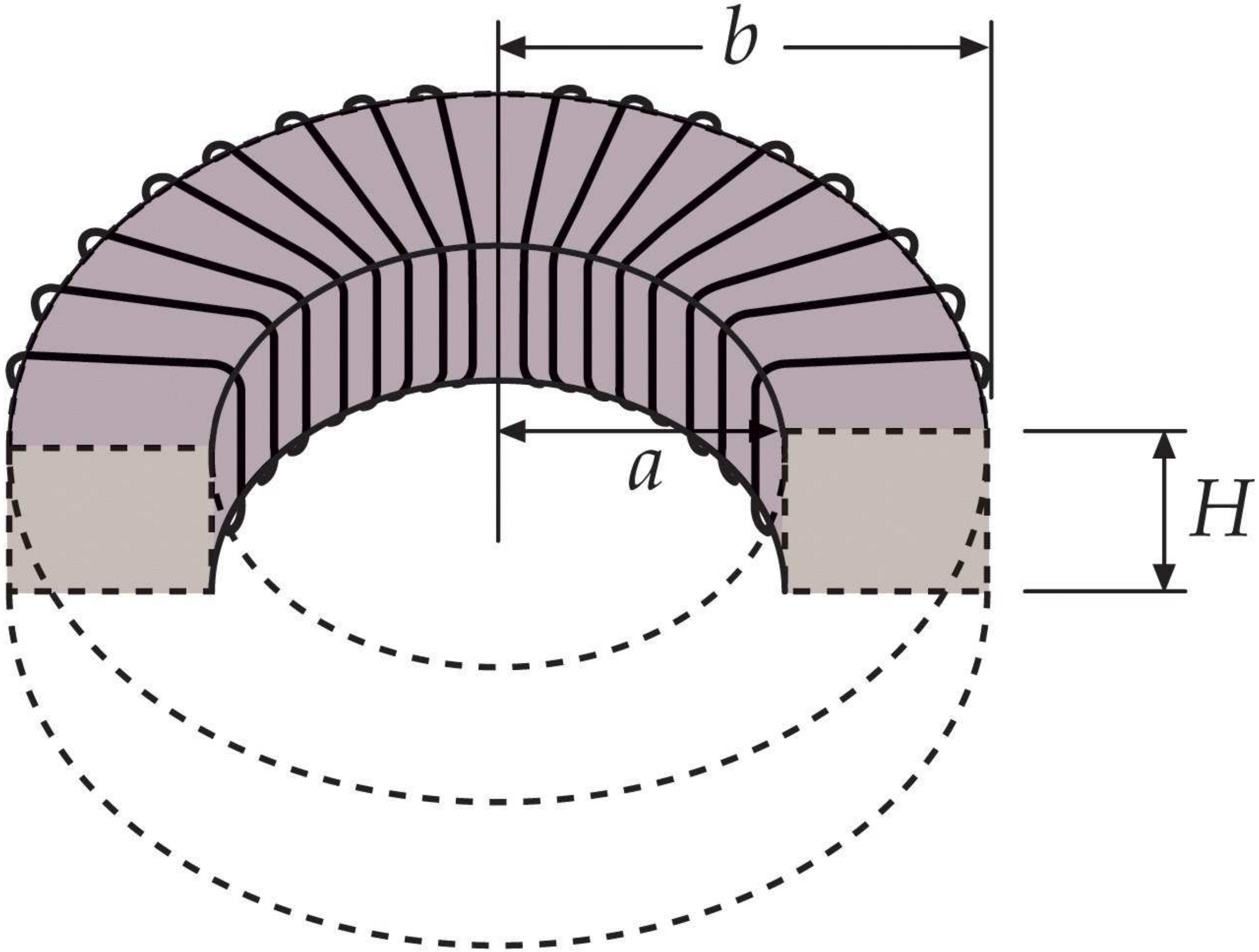
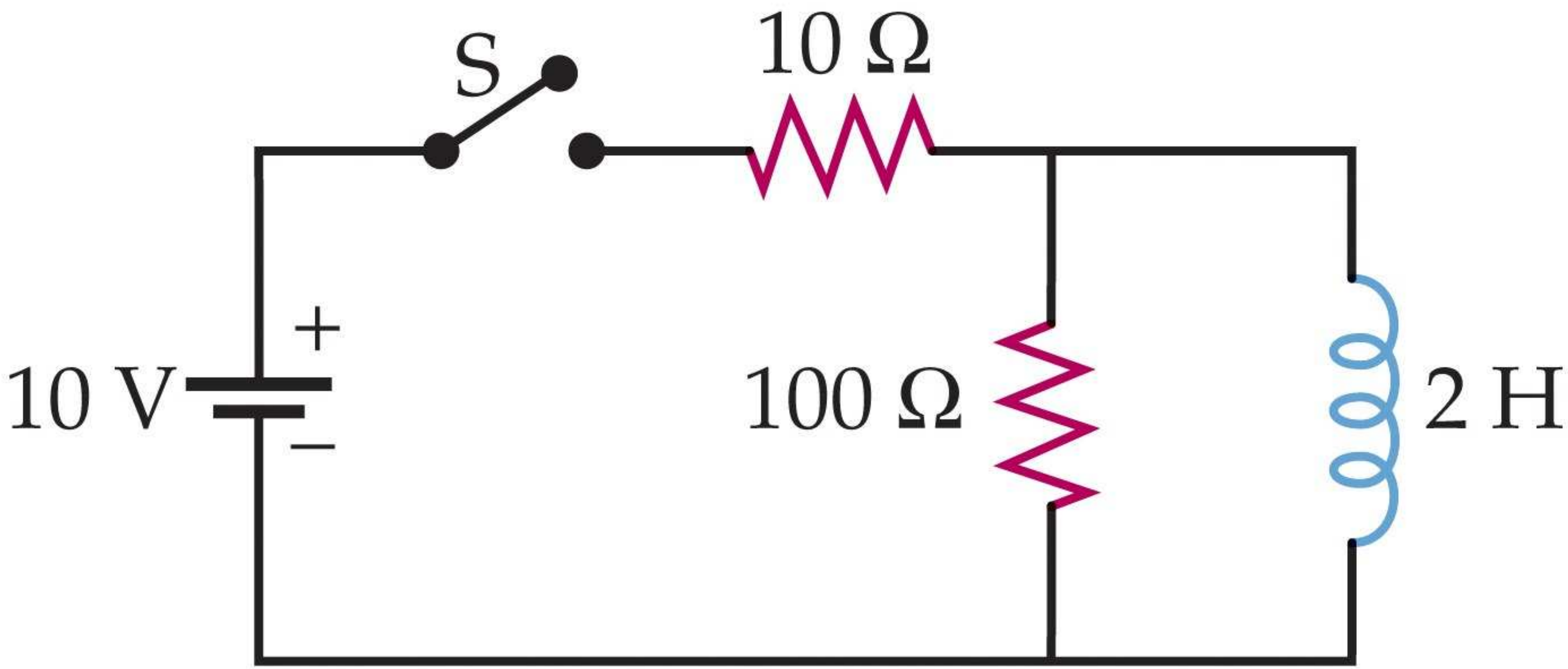


28.75



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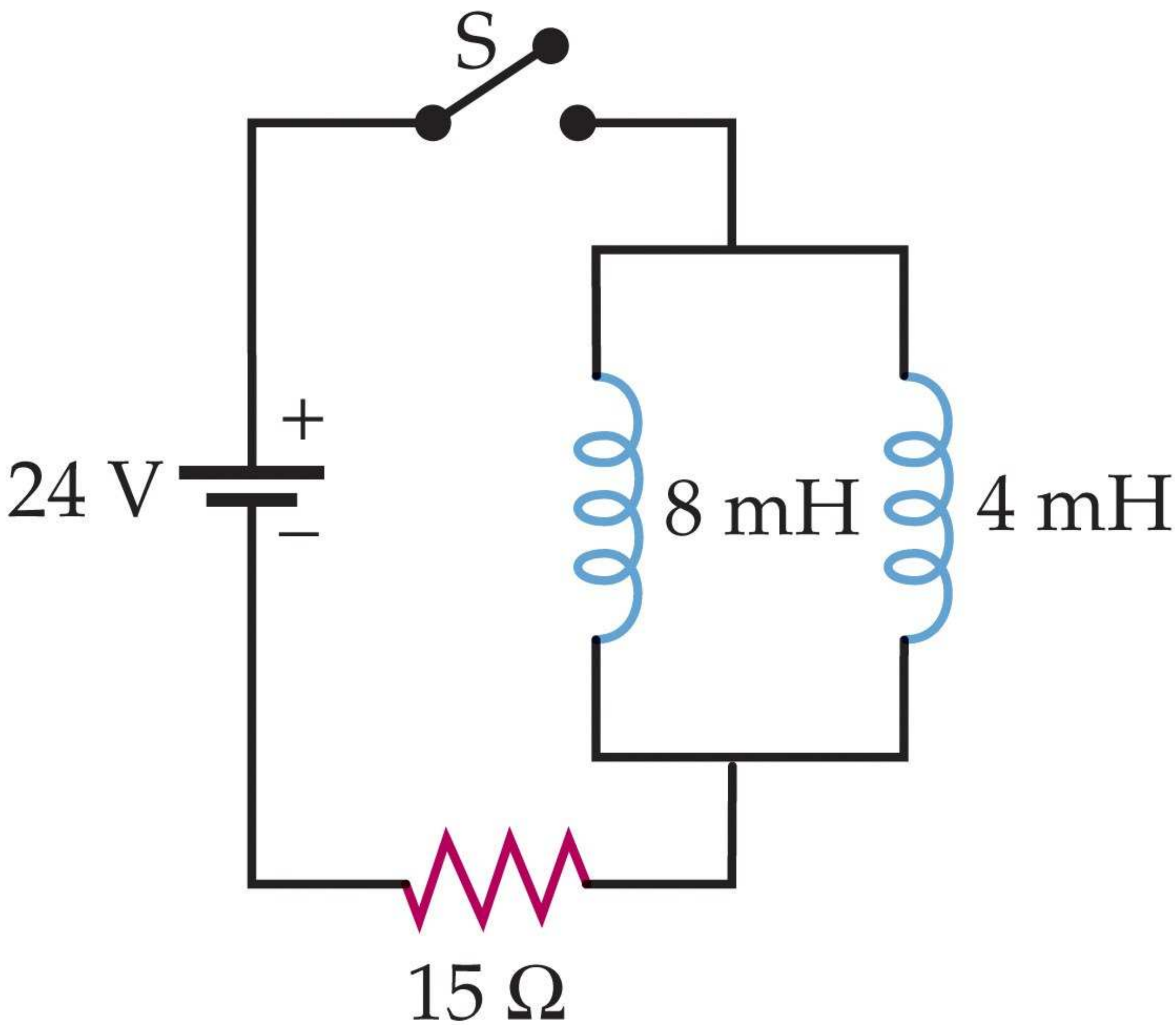

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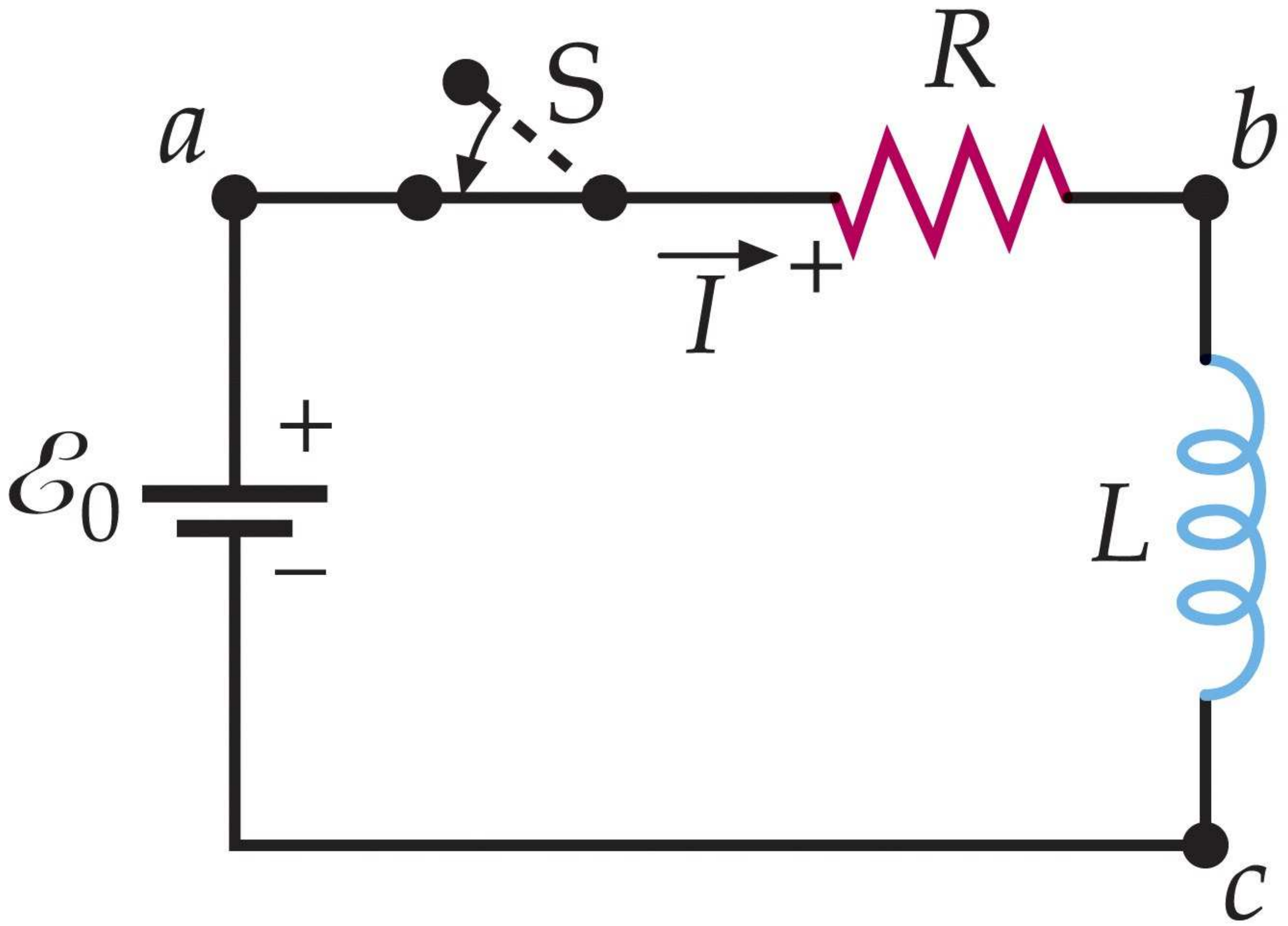

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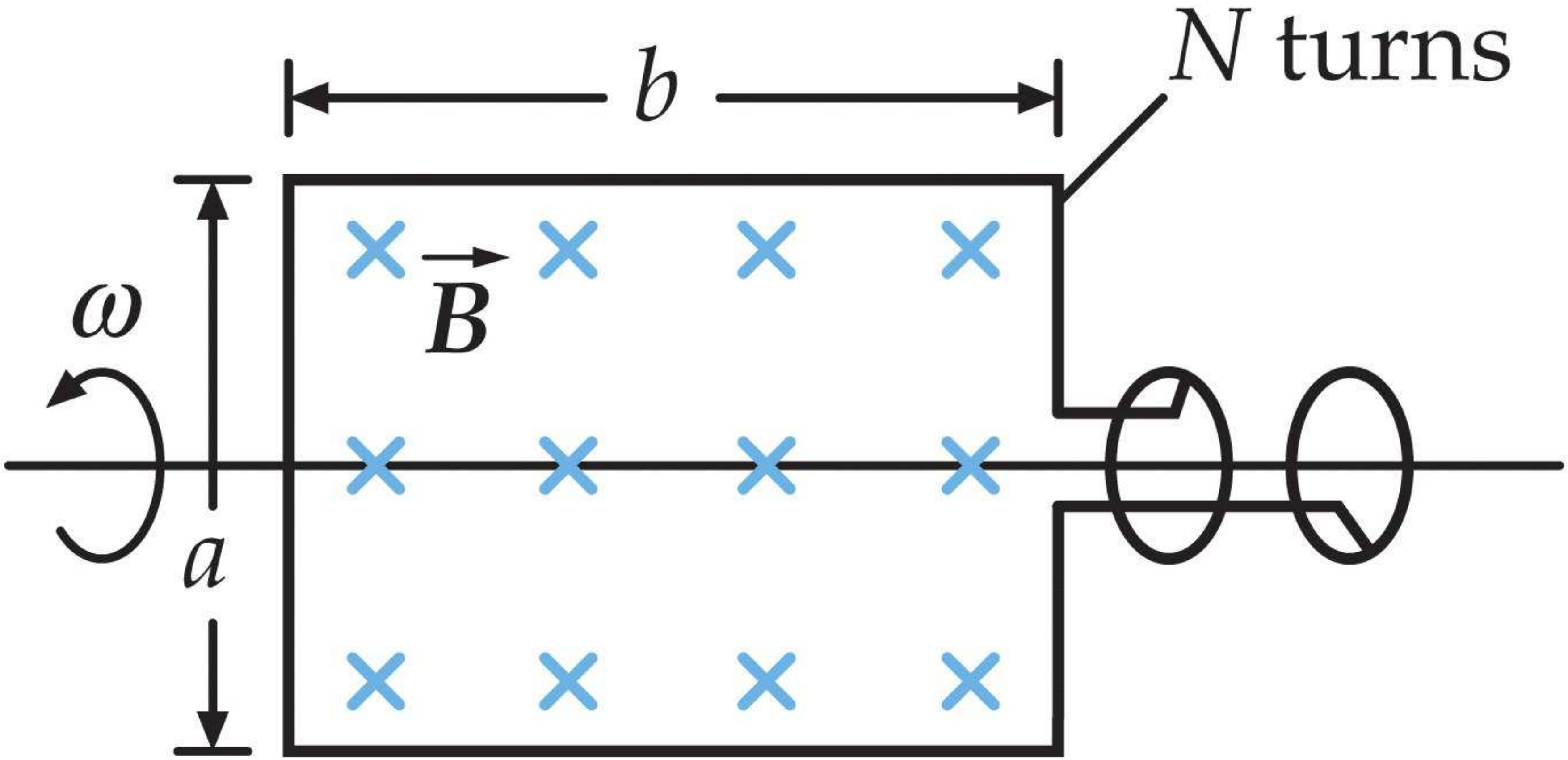

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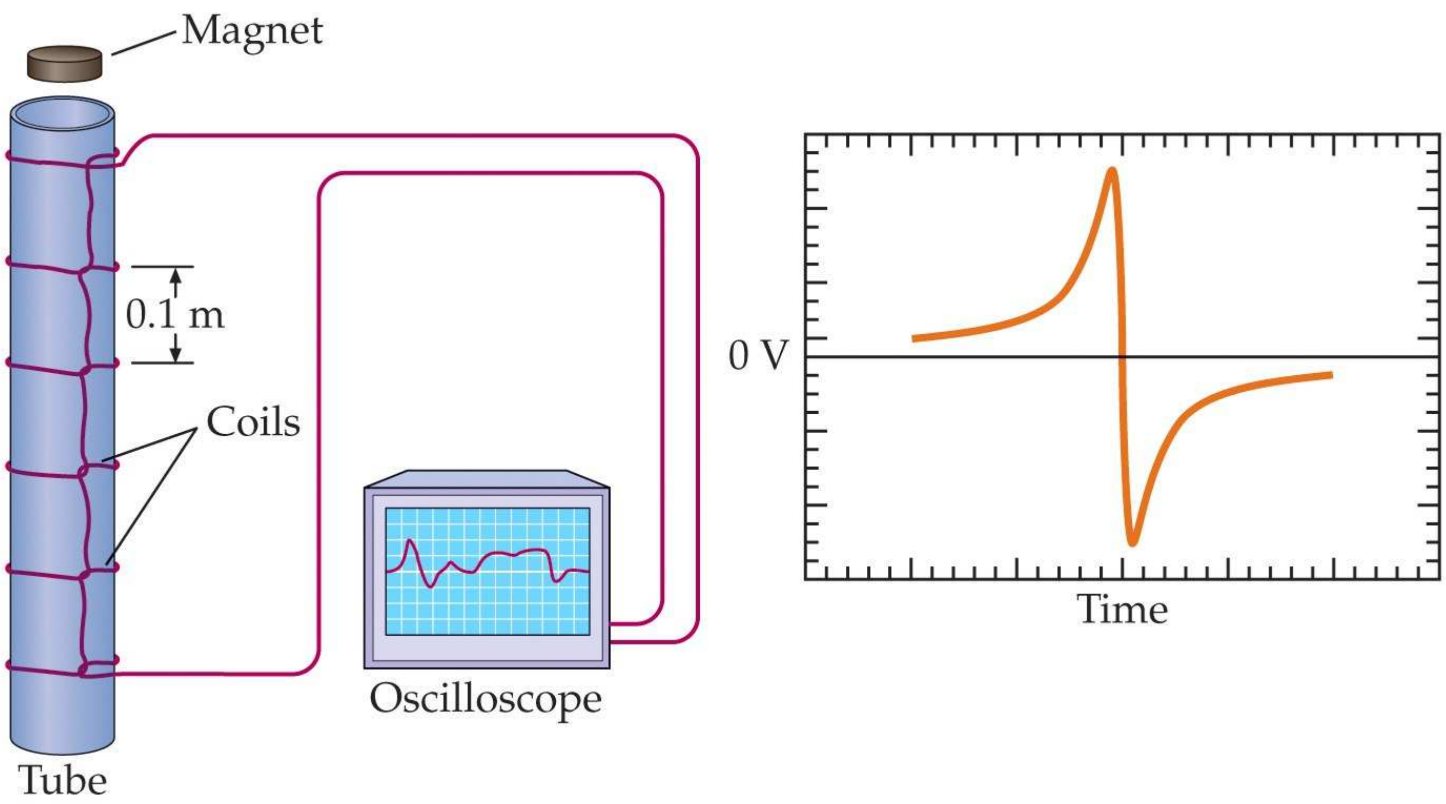

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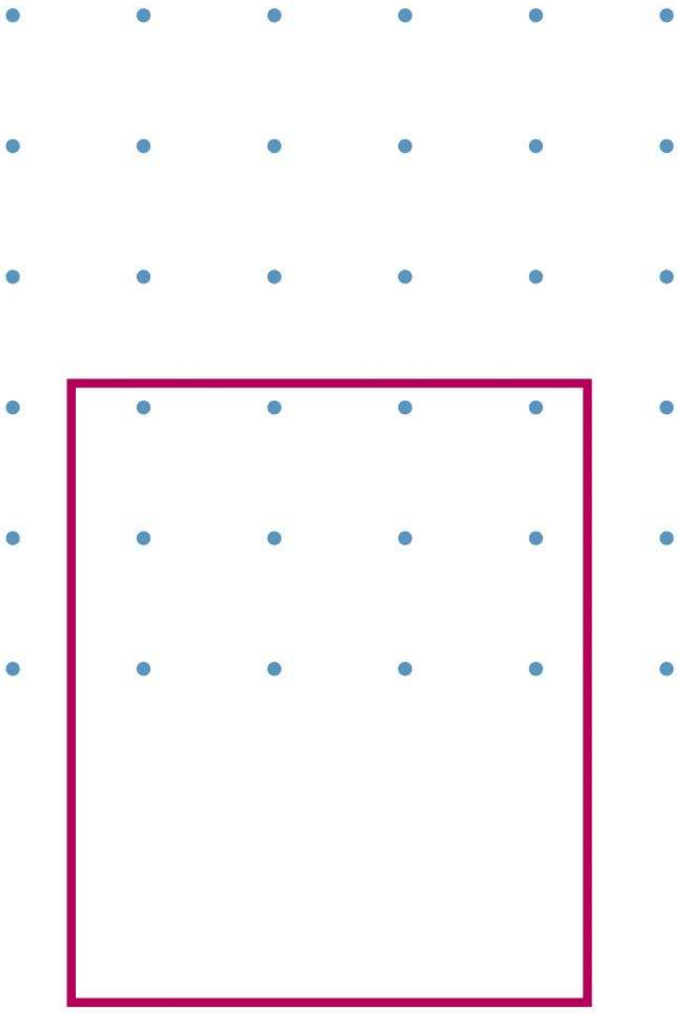

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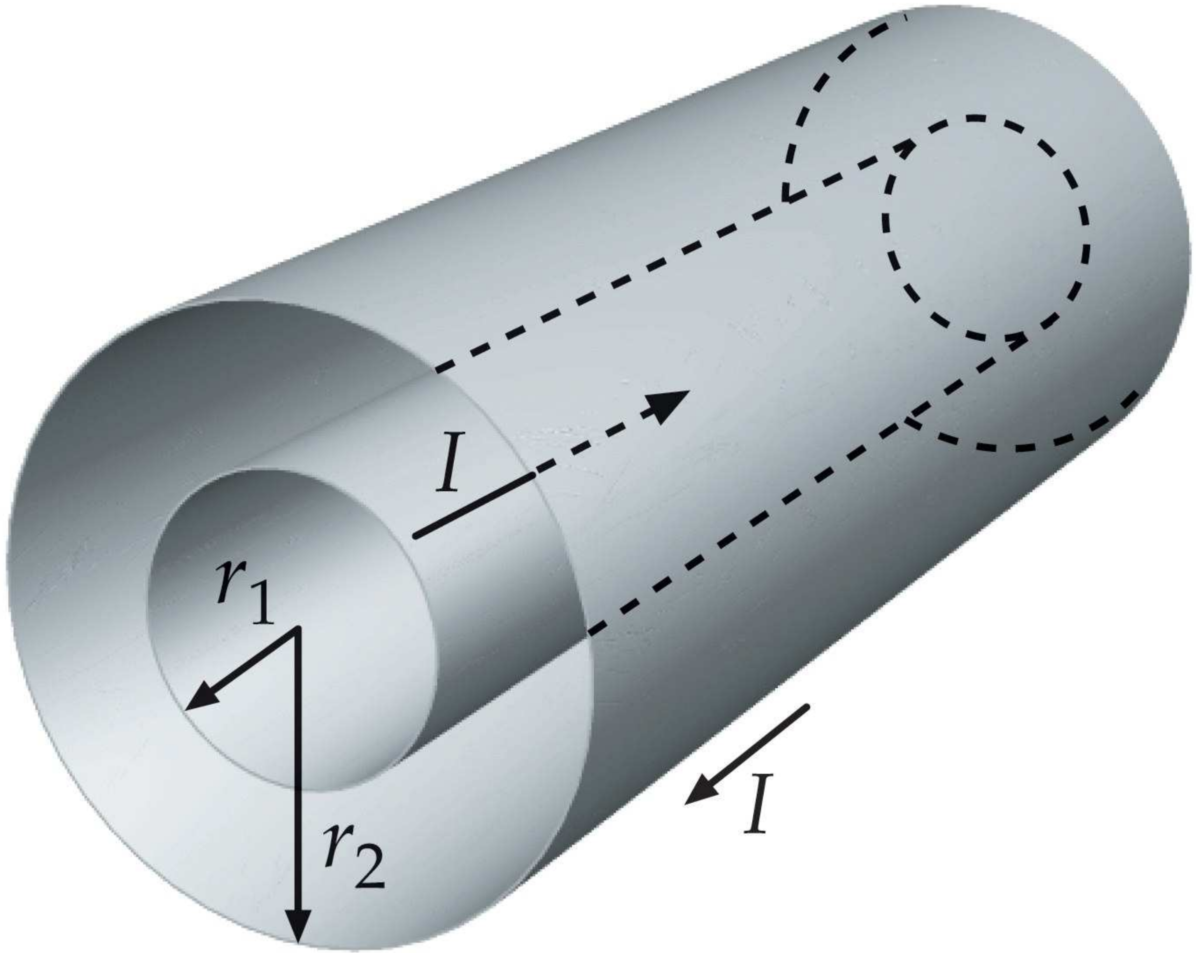

28.96