

Motional EMF

Lecture 21

Announcements

- Reading for Friday: 28-4 to 28-5
- Exam Thursday next week (3/5).

Electrodynamics & the Maxwell Equations

- Gauss Law (E):

$$\oint_{\mathcal{M}} d^2A \hat{n} \cdot \vec{E} = Q_{\text{inside}}/\epsilon_0$$

- Gauss Law (B):

$$\oint_{\mathcal{M}} d^2A \hat{n} \cdot \vec{B} = 0$$

- Ampère Law:

$$\oint_{\partial\mathcal{M}} \vec{d}\ell \cdot \vec{B} = \mu_0 I + \mu_0 \epsilon_0 \frac{d}{dt} \int_{\mathcal{M}} d^2A \hat{n} \cdot \vec{E}$$

- Faraday Law:

$$\oint_{\partial\mathcal{M}} \vec{d}\ell \cdot \vec{E} = - \frac{d}{dt} \int_{\mathcal{M}} d^2A \hat{n} \cdot \vec{B}$$

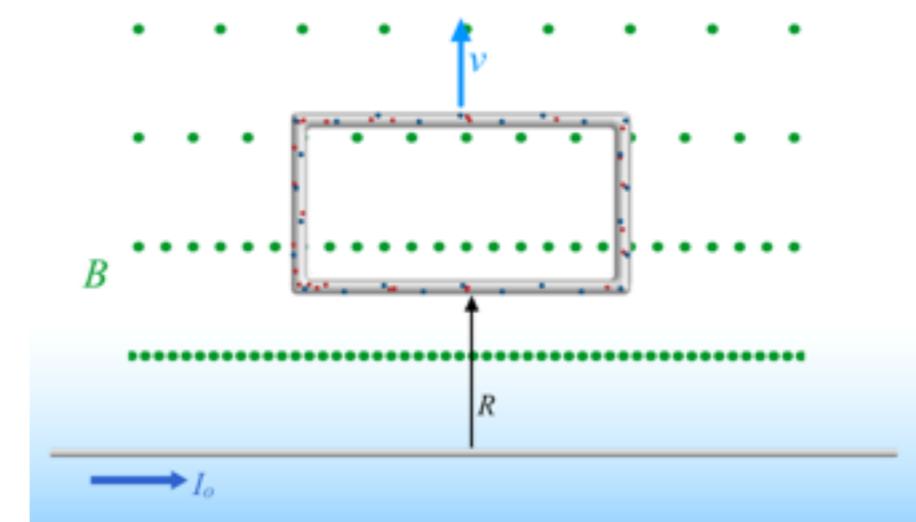
Preview: Faraday Law of Induction

- Changes in the Magnetic Flux through a loop induces an EMF:

$$\mathcal{E} = -\frac{d}{dt}\Phi_B$$

$$\Phi_B \equiv \int_{\mathcal{M}} d^2 A \hat{n} \cdot \vec{B}$$

- Why isn't the flux exactly zero?



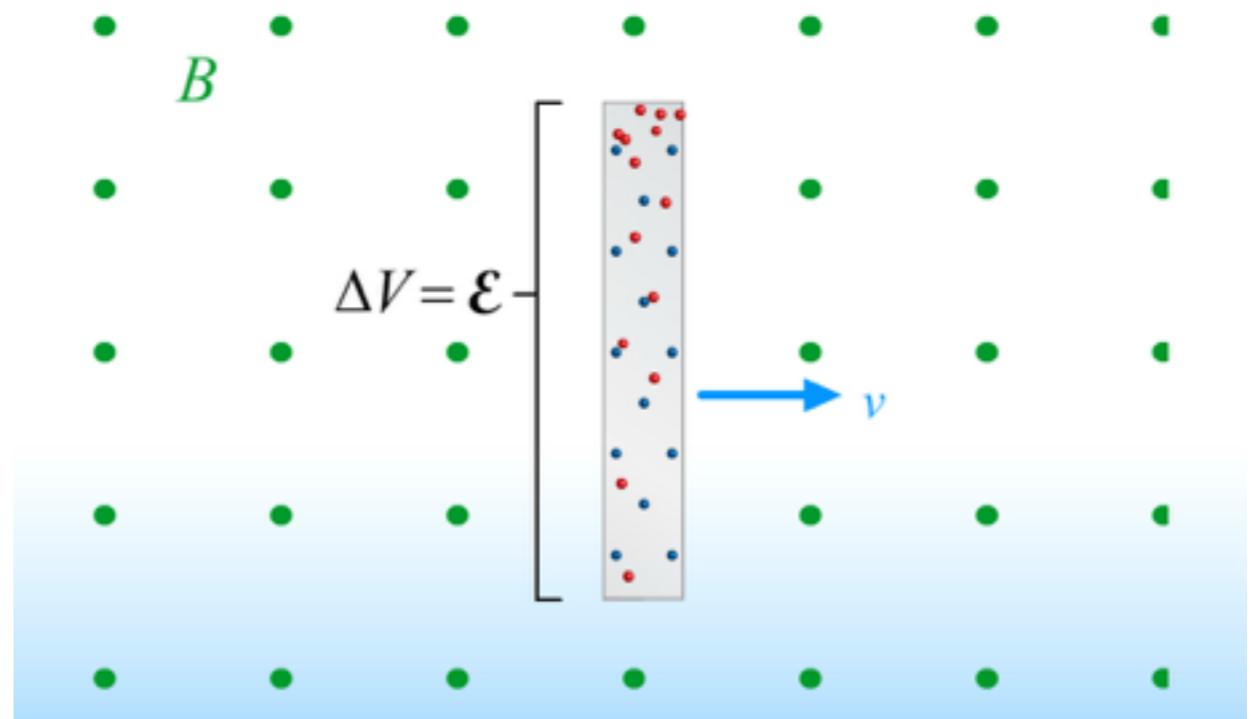
- **Transformer EMF:** Changes in B generate E (Friday)
- **Motional EMF:** Changes in M generates F_B (Today)

Motional EMF ~ Lorentz Force Law

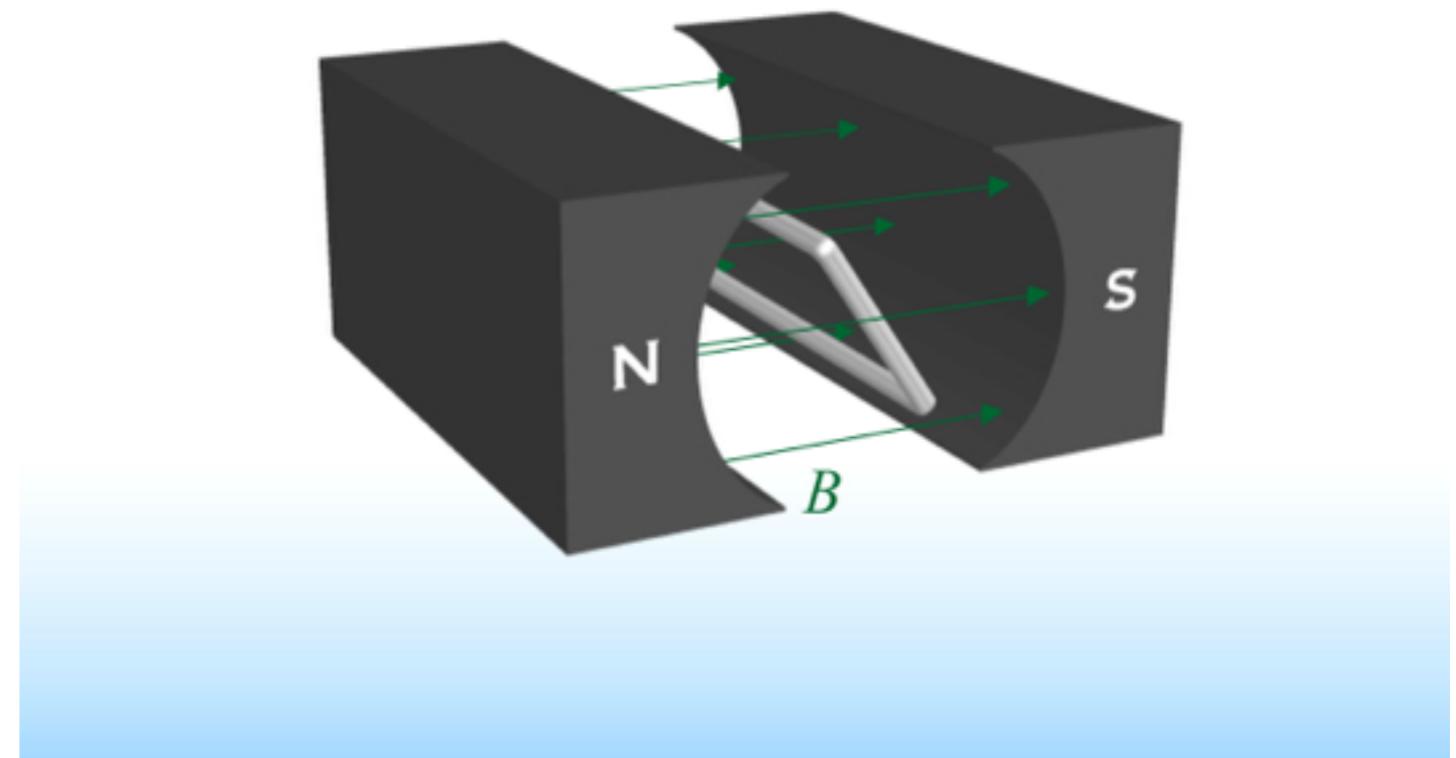
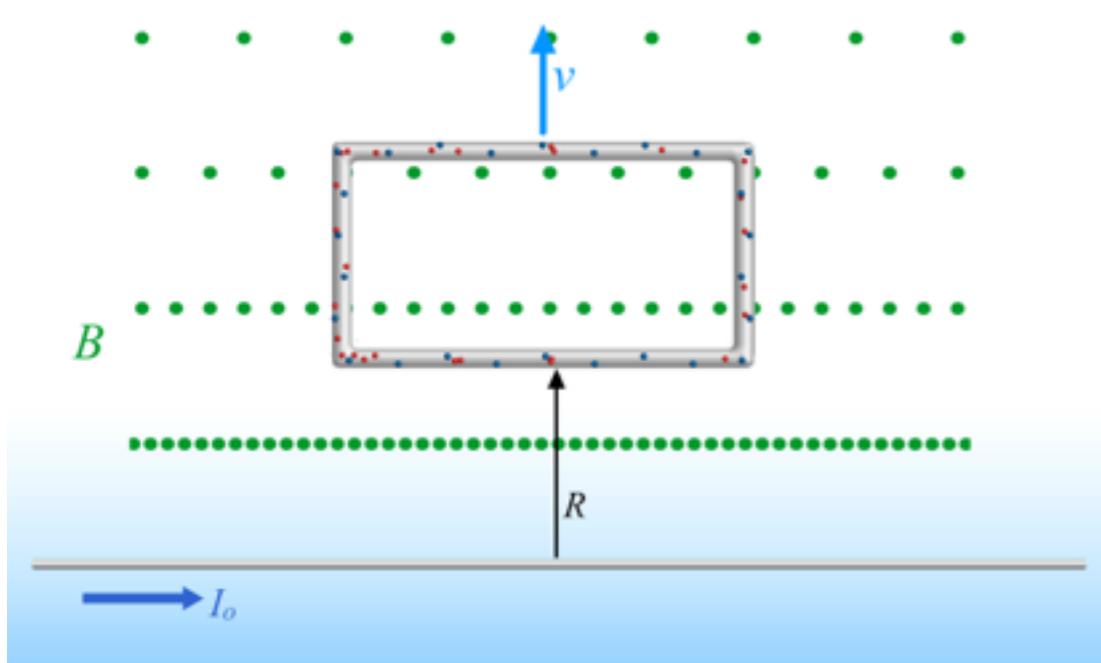
- Conductor moving in a magnetic field

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

$$\vec{F}_B = evB \hat{j}$$



More examples...



Equilibrium: Using force balance to deduce E.

- Assume Equilibrium

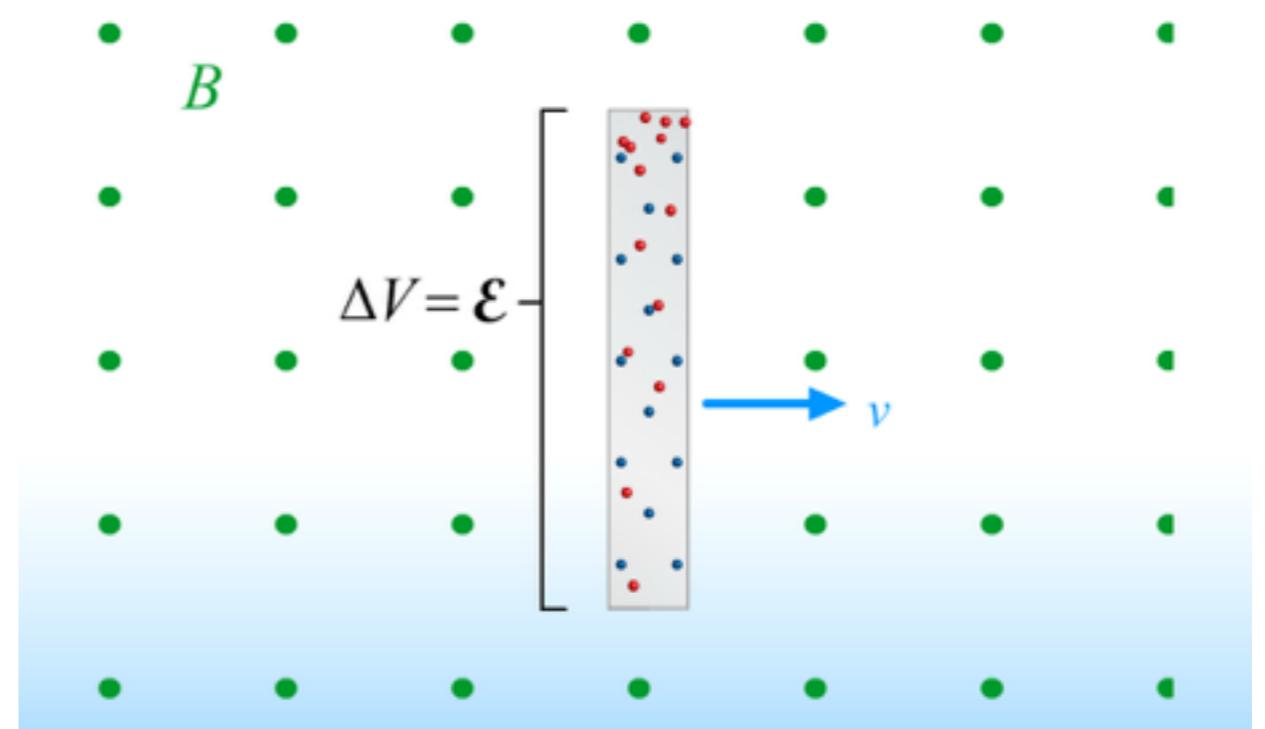
$$0 = \vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

$$\vec{F}_B = evB\hat{j}$$

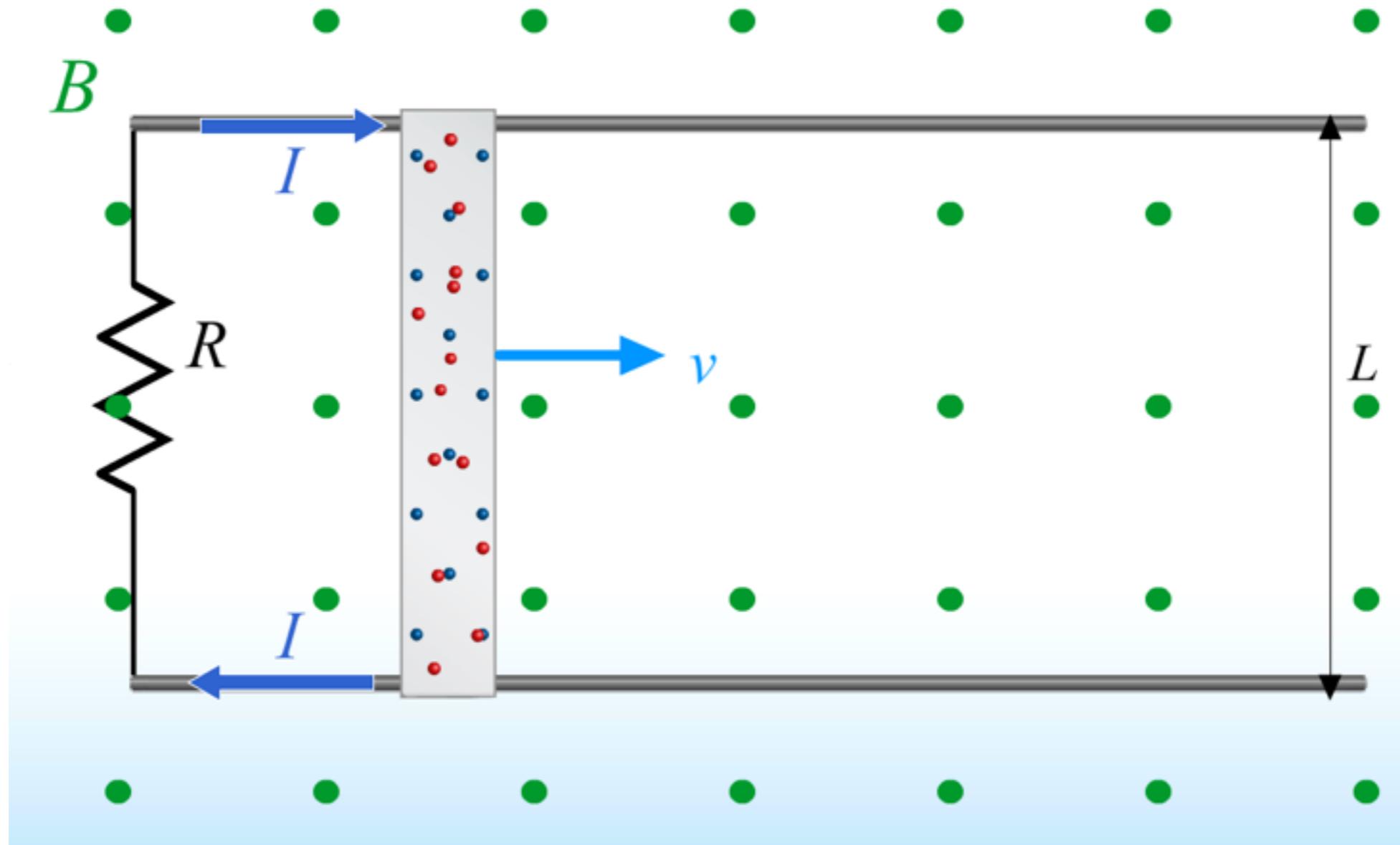
- (Overhead)
- Result:

$$\vec{E} = vB\hat{j}$$

$$\mathcal{E} = -LvB$$

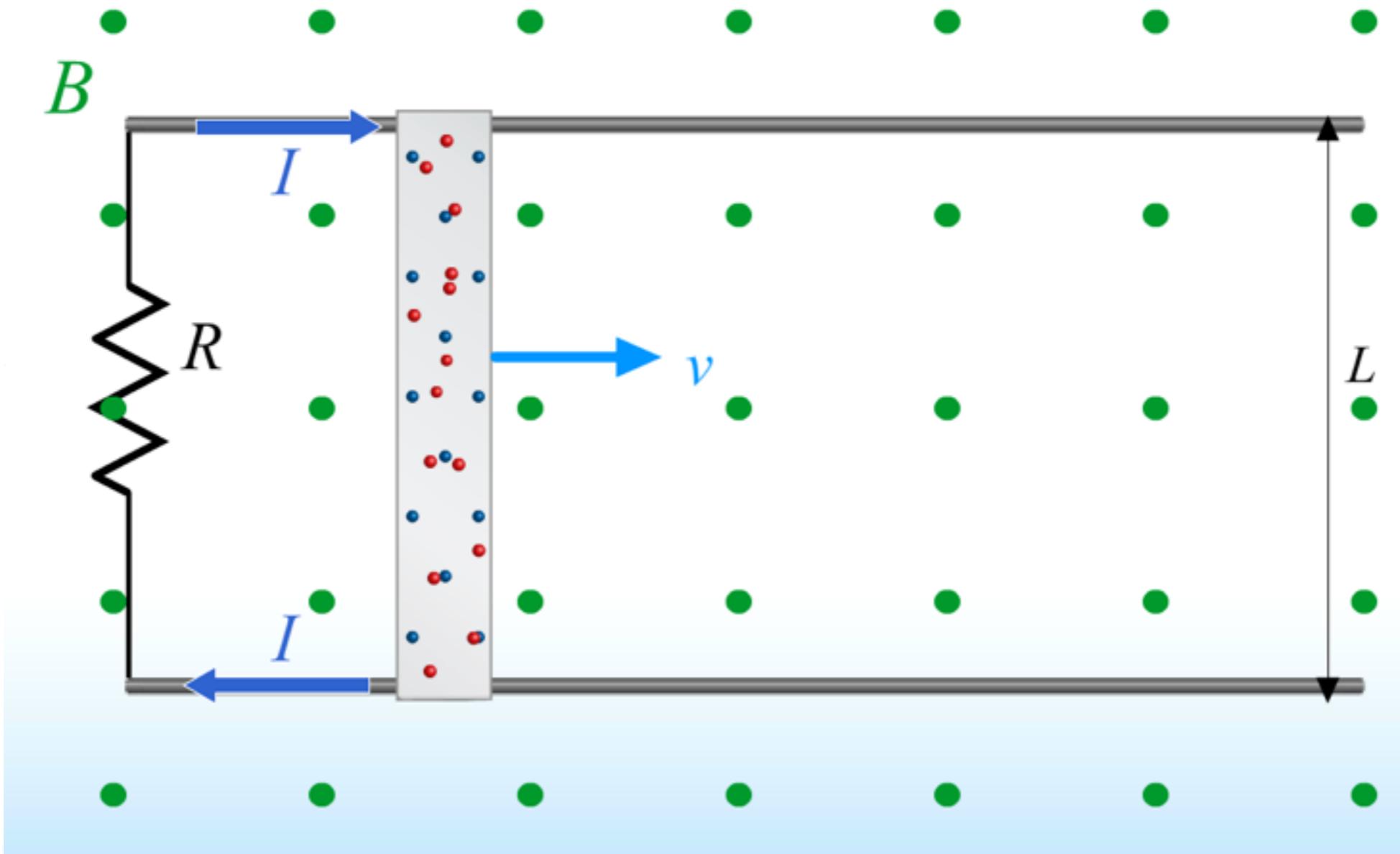


Demo: Is this EMF real?

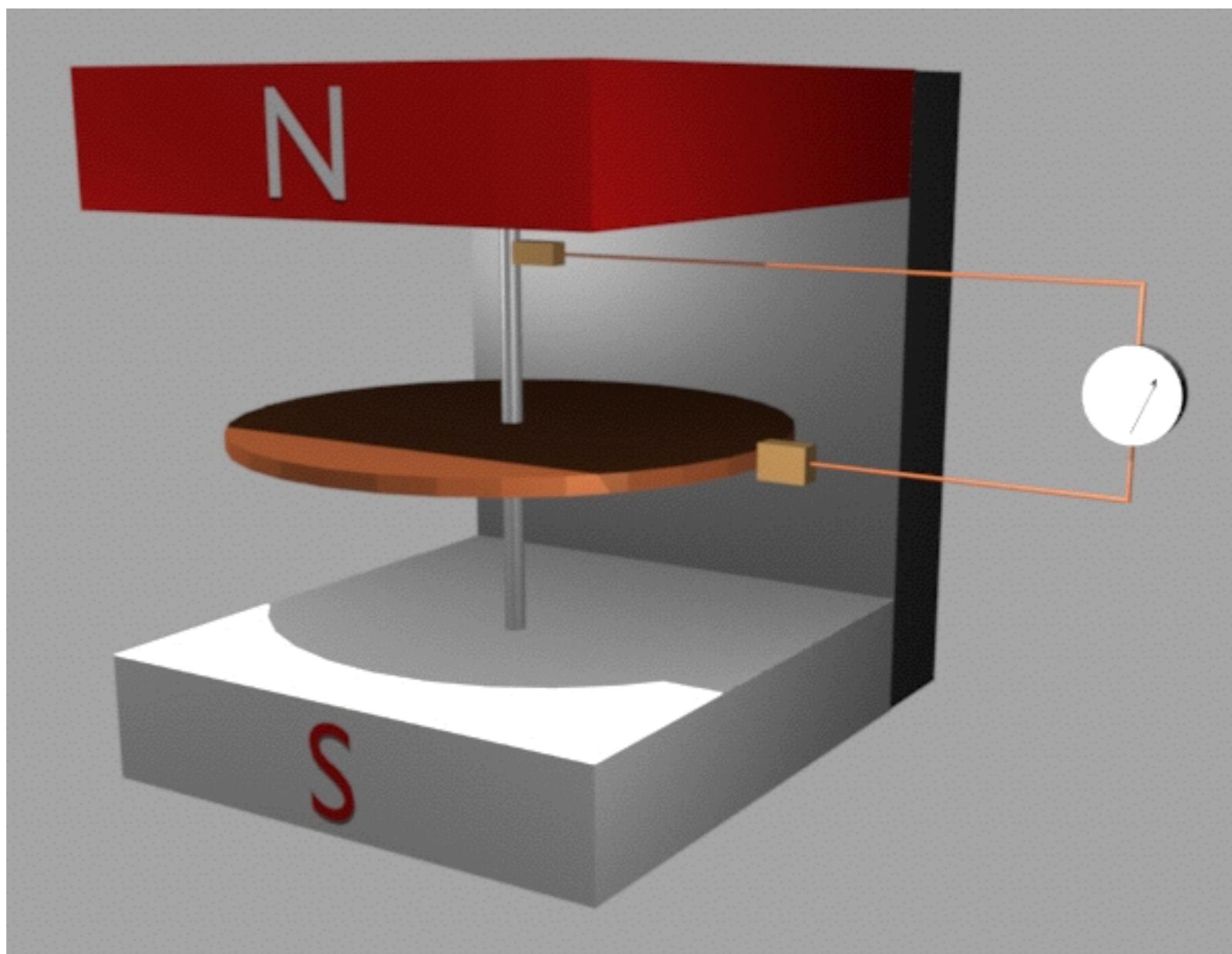


- Drives current I !

Where does the energy come from?

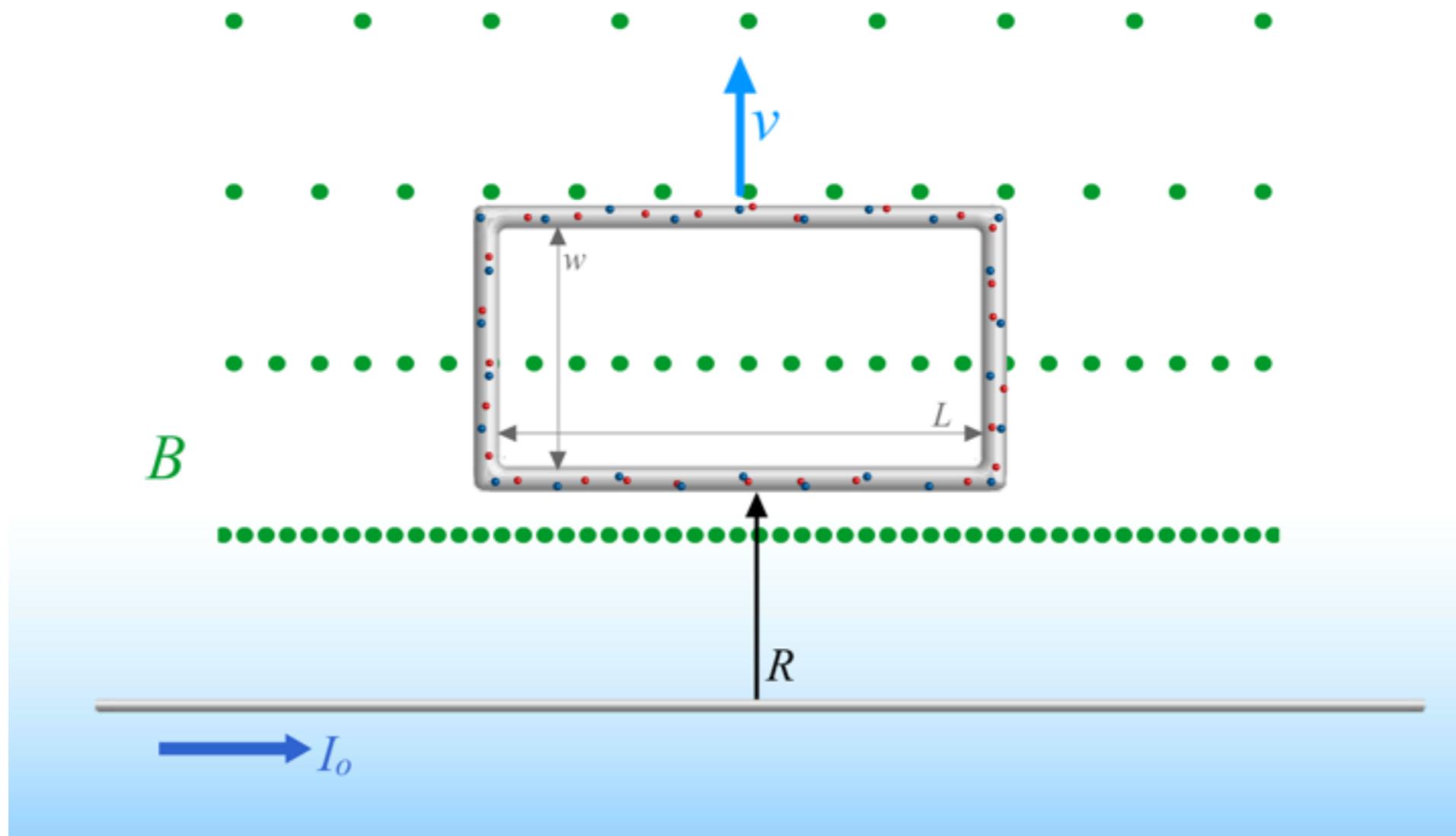


Question: Does the Faraday disk work as a motor?



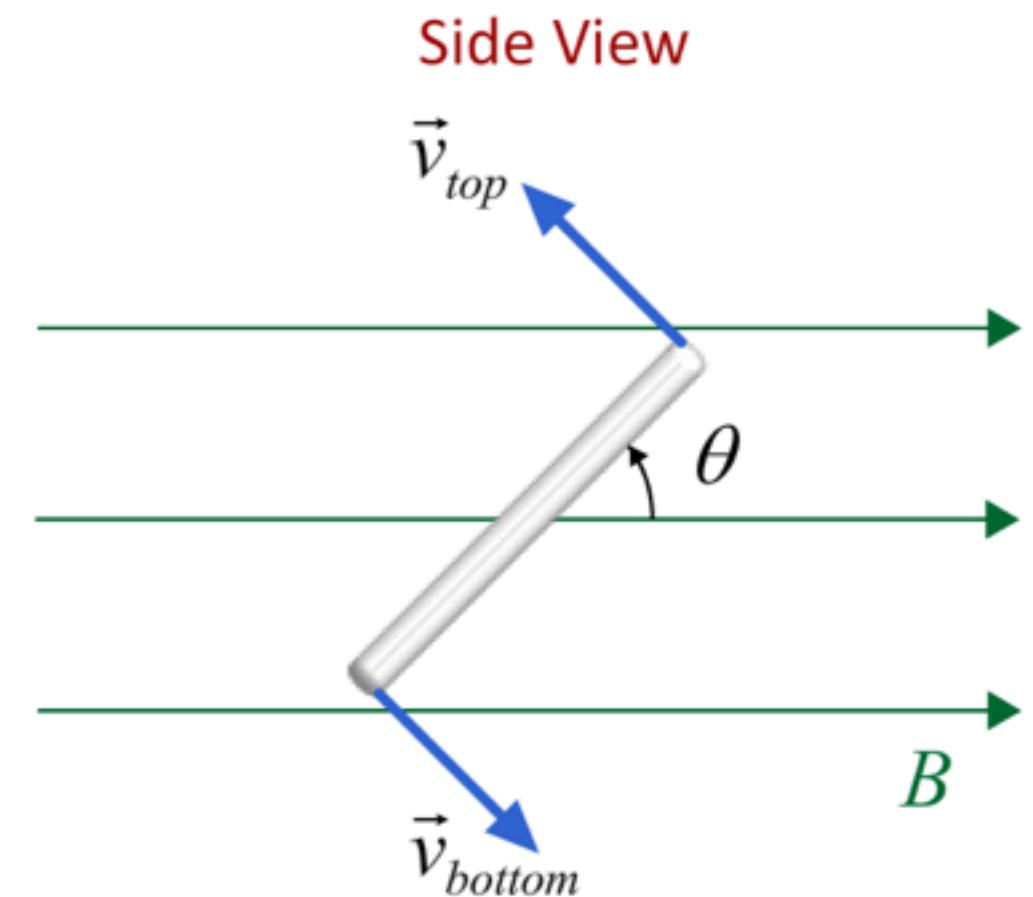
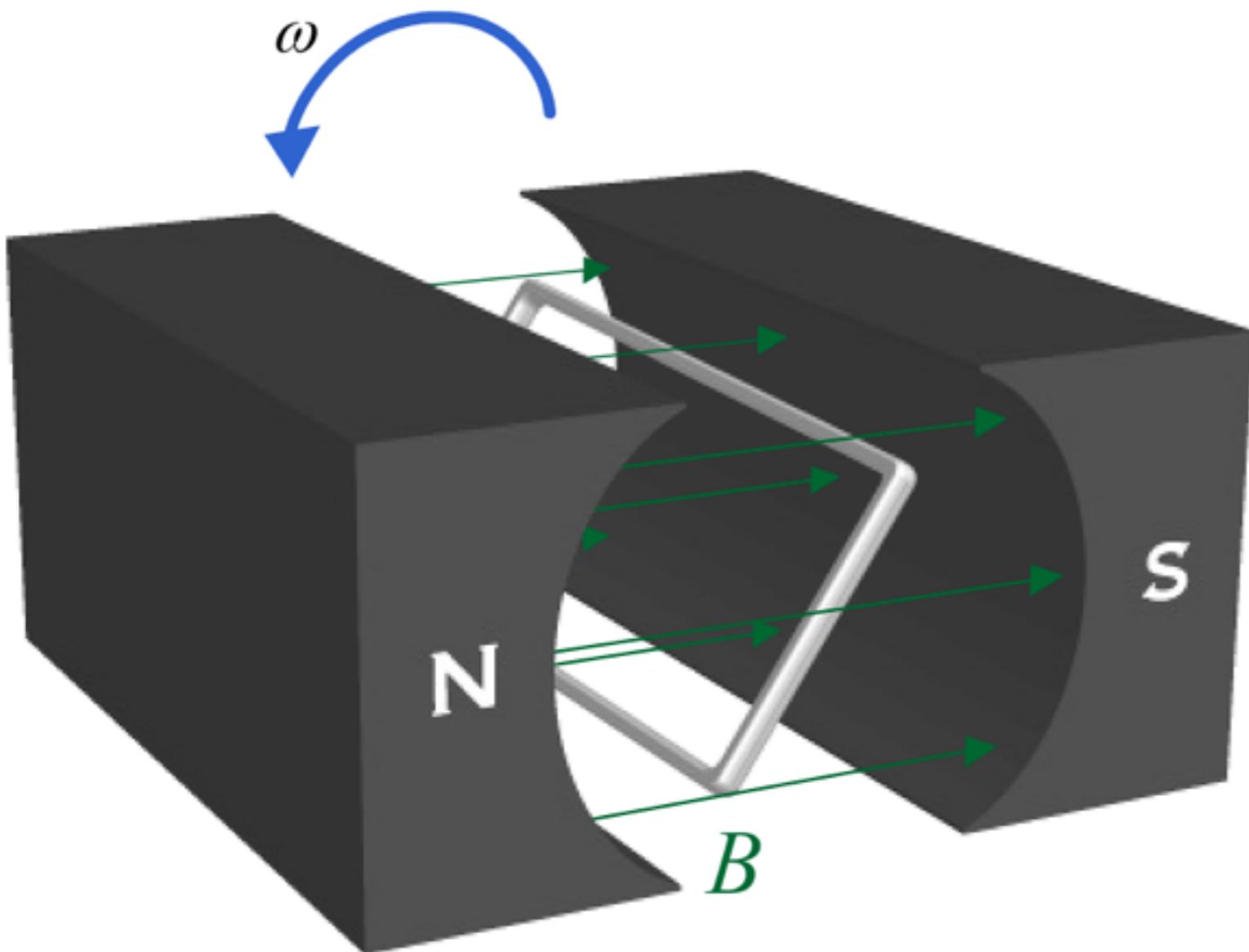
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Another example...



- Result: $\mathcal{E} = vL(B_{\text{Bottom}} - B_{\text{Top}})$

Generator (Demo)



Result: $\mathcal{E} = 2vLB \cos \theta$

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