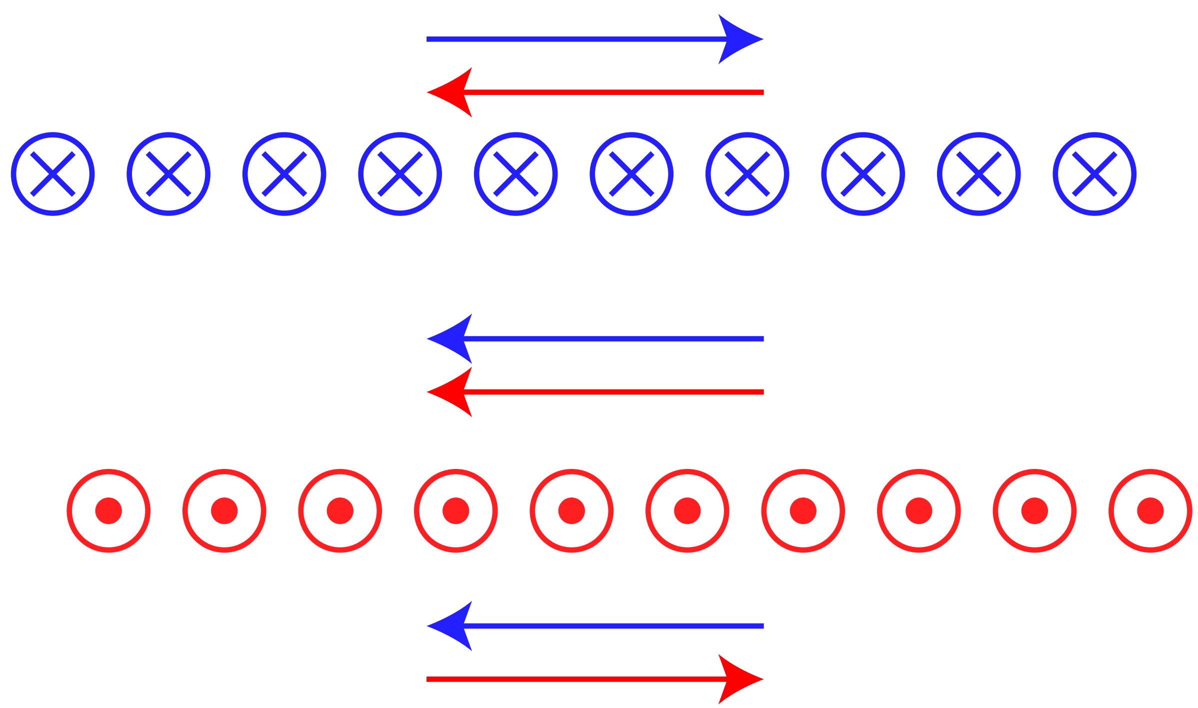
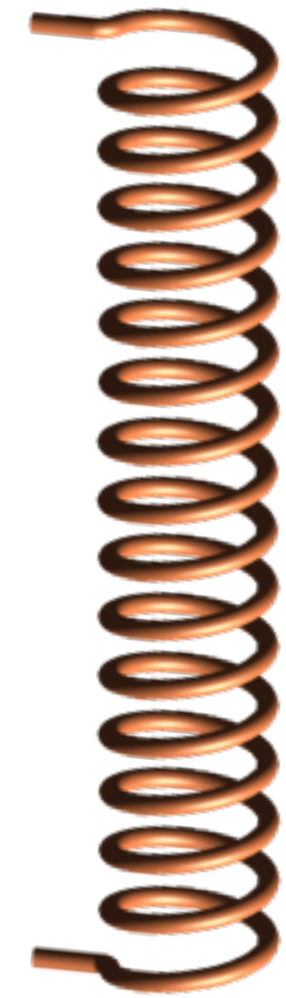
Motional EMF

Lecture 21

B field for an ∞ solenoid

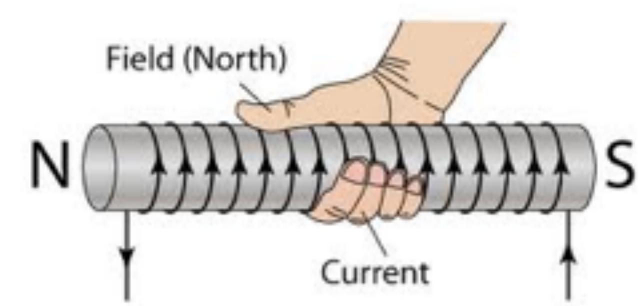
- Intuitive picture: ~ 2 infinite sheets





- Field is ~ zero outside

$$B = \mu_0 n I$$



Electrodynamics & the Maxwell Equations

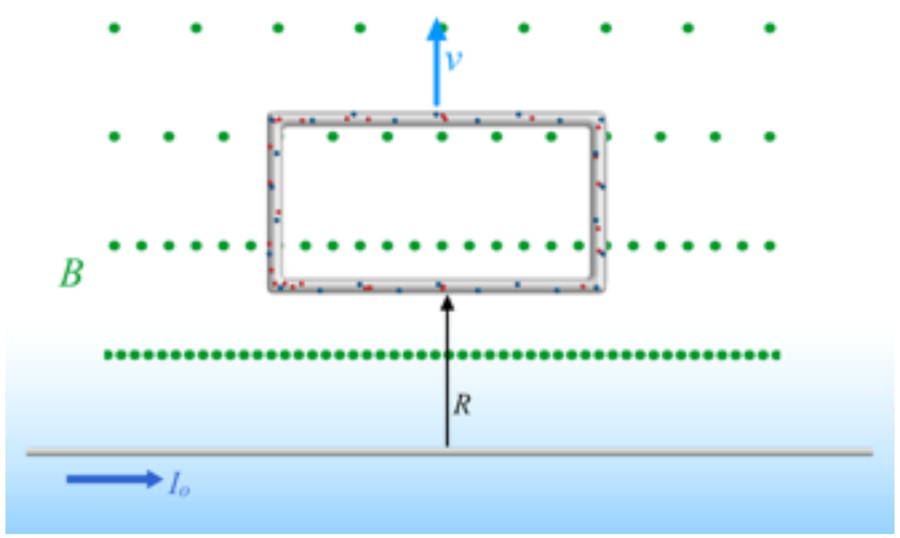
- Gauss Law (E): $$\oint_{\mathcal{M}} d^2A\ \hat{n} \cdot \vec{E} = Q_{\text{inside}}/\epsilon_0$$
- Gauss Law (B): $$\oint_{\mathcal{M}} d^2A\ \hat{n} \cdot \vec{B} = 0$$
- Ampère Law: $$\oint_{\partial\mathcal{M}} d\vec{\ell} \cdot \vec{B} = \mu_0 I + \mu_0 \epsilon_0 \frac{d}{dt} \int_{\mathcal{M}} d^2A\, \hat{n} \cdot \vec{E}$$
- Faraday Law: $$\oint_{\partial\mathcal{M}} d\vec{\ell} \cdot \vec{E} = -\frac{d}{dt} \int_{\mathcal{M}} d^2A\, \hat{n} \cdot \vec{B}$$

Preview: Faraday Law of Induction

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

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

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



- Why isn't the flux exactly zero?

- **Transformer EMF:** Changes in B generate E (Friday)

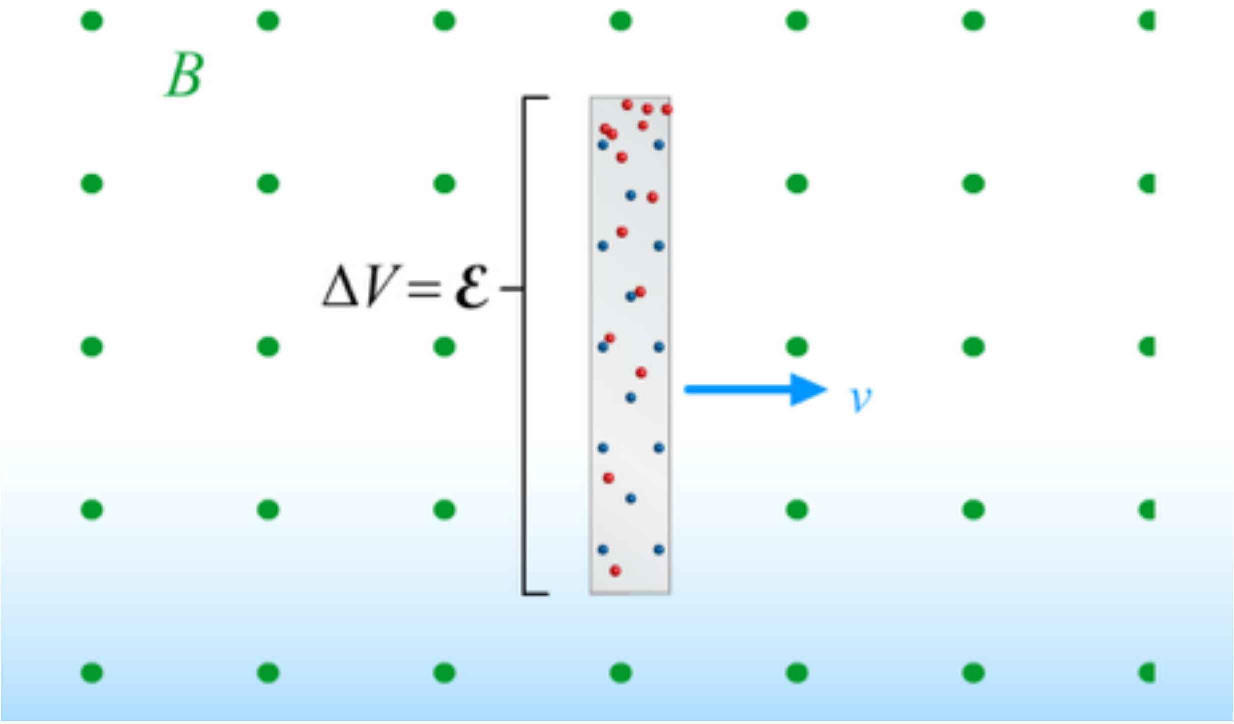
- **Motional EMF:** Changes in M generates F_B (Today)

Motional EMF ~ Lorentz Force Law

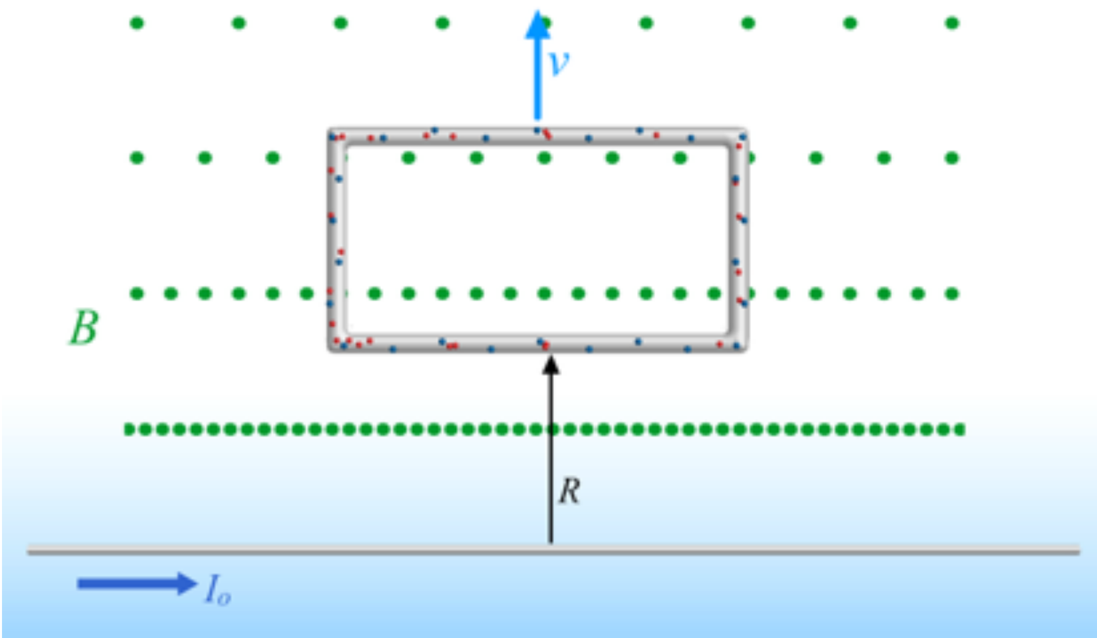
- Conductor moving in a magnetic field

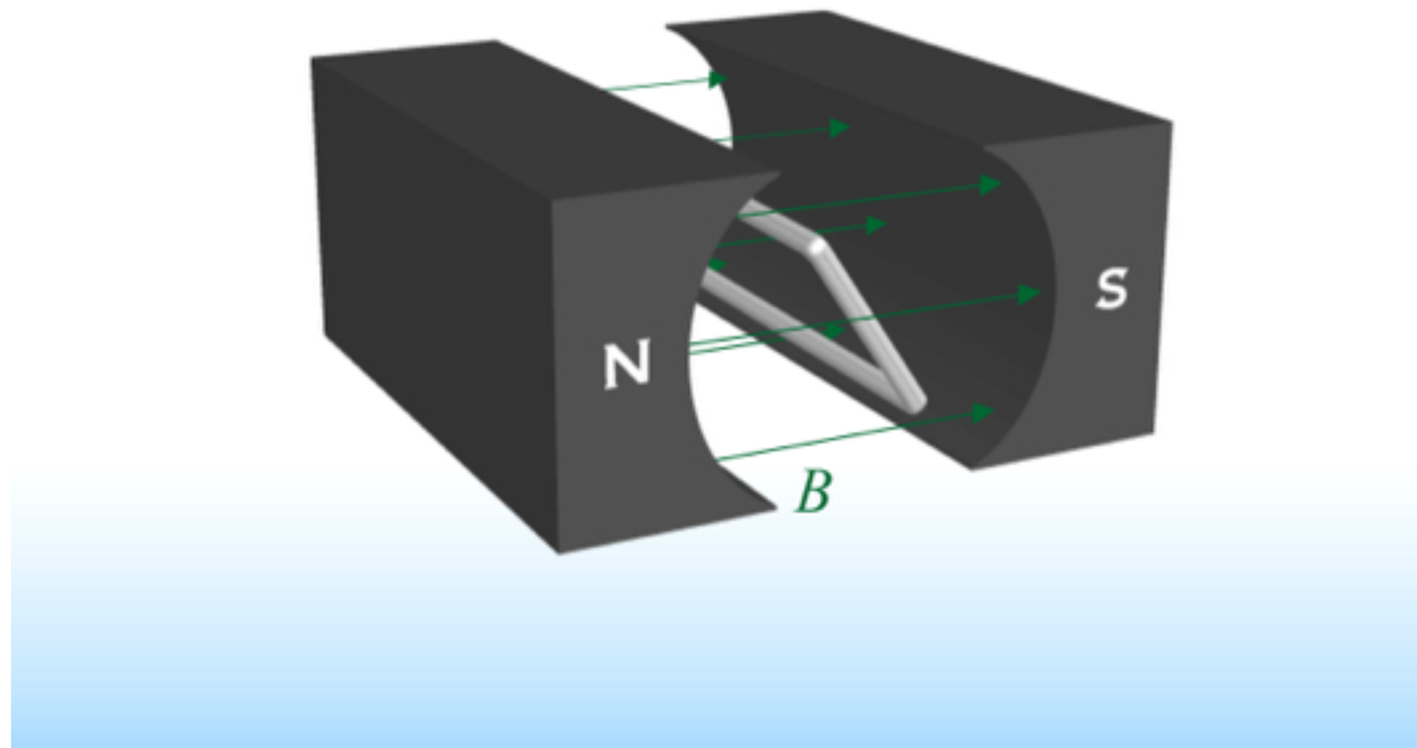
$$\vec{F}_B = q\vec{v} \times \vec{B}$$

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



More examples…



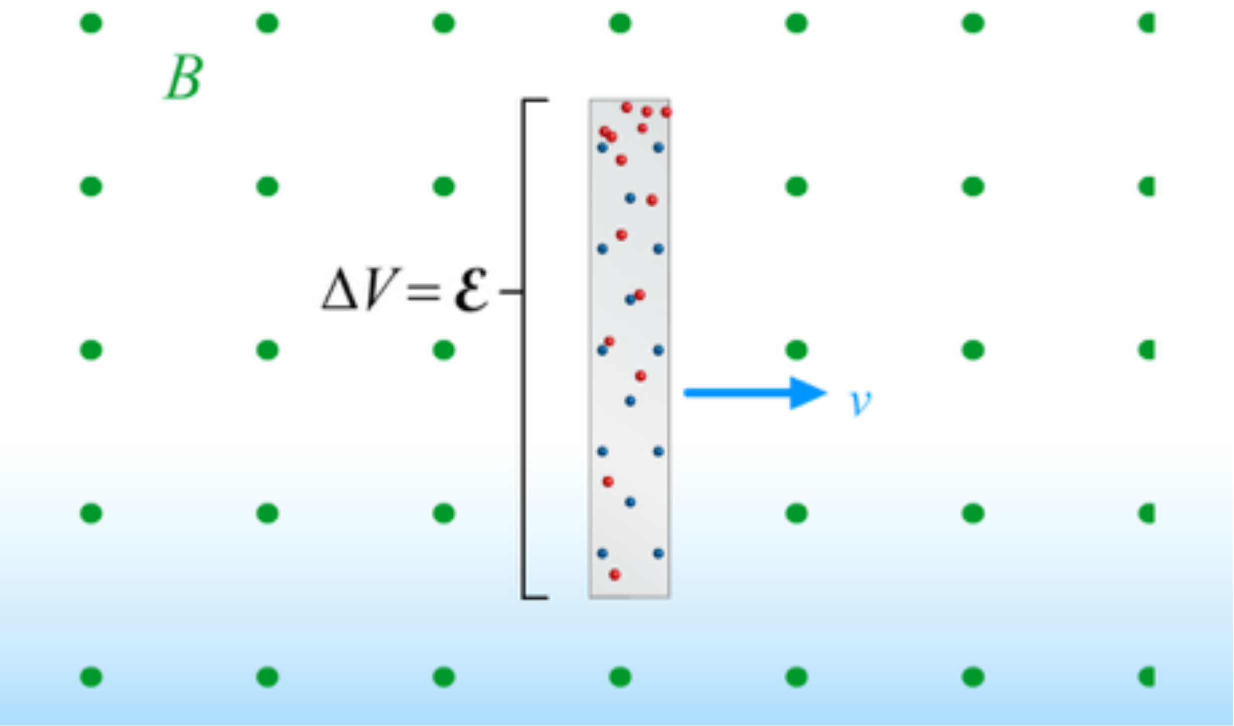


Equilibrium: Using force balance to deduce E.

- Assume Equilibrium

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

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



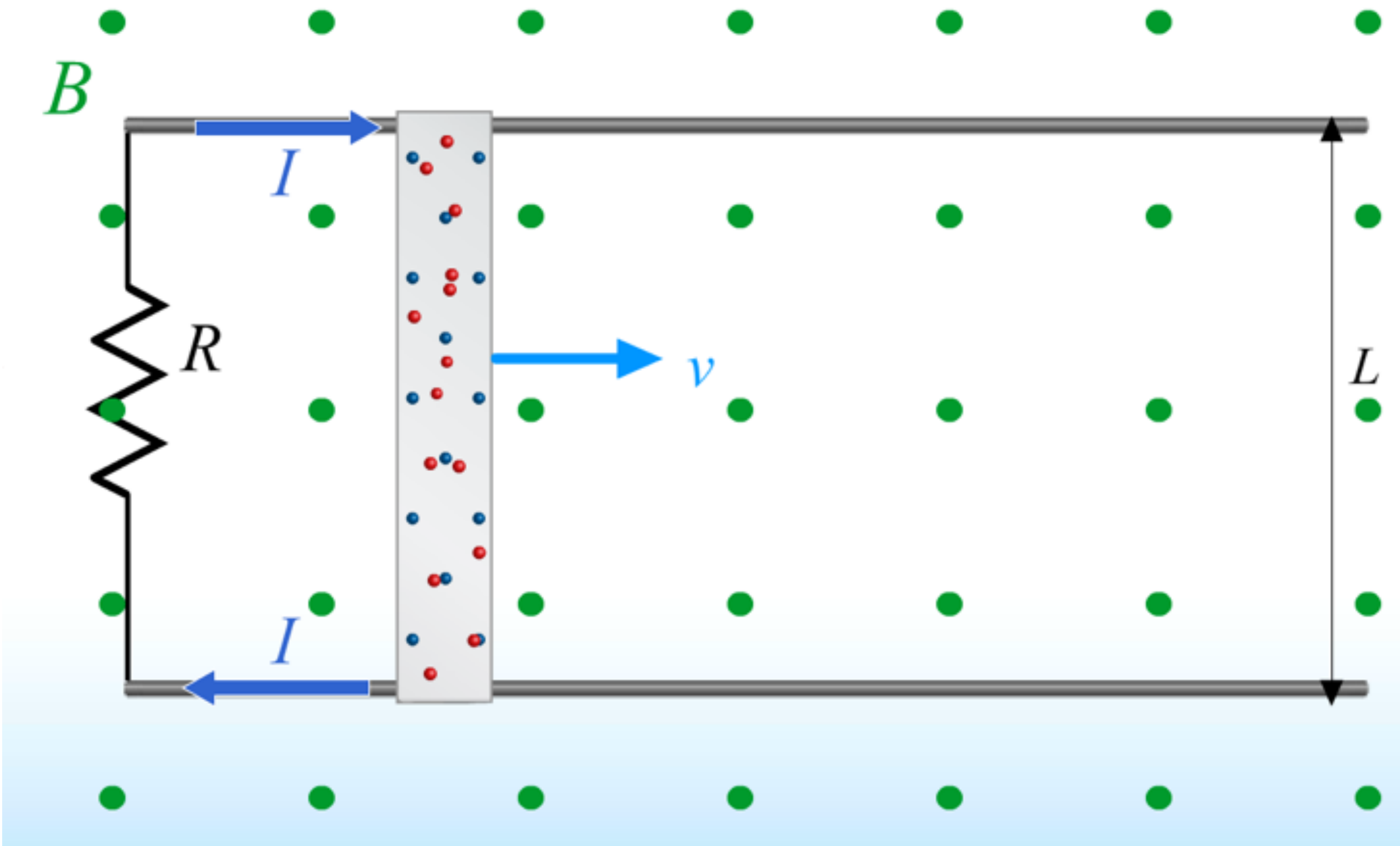
- (Overhead)

- Result:

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

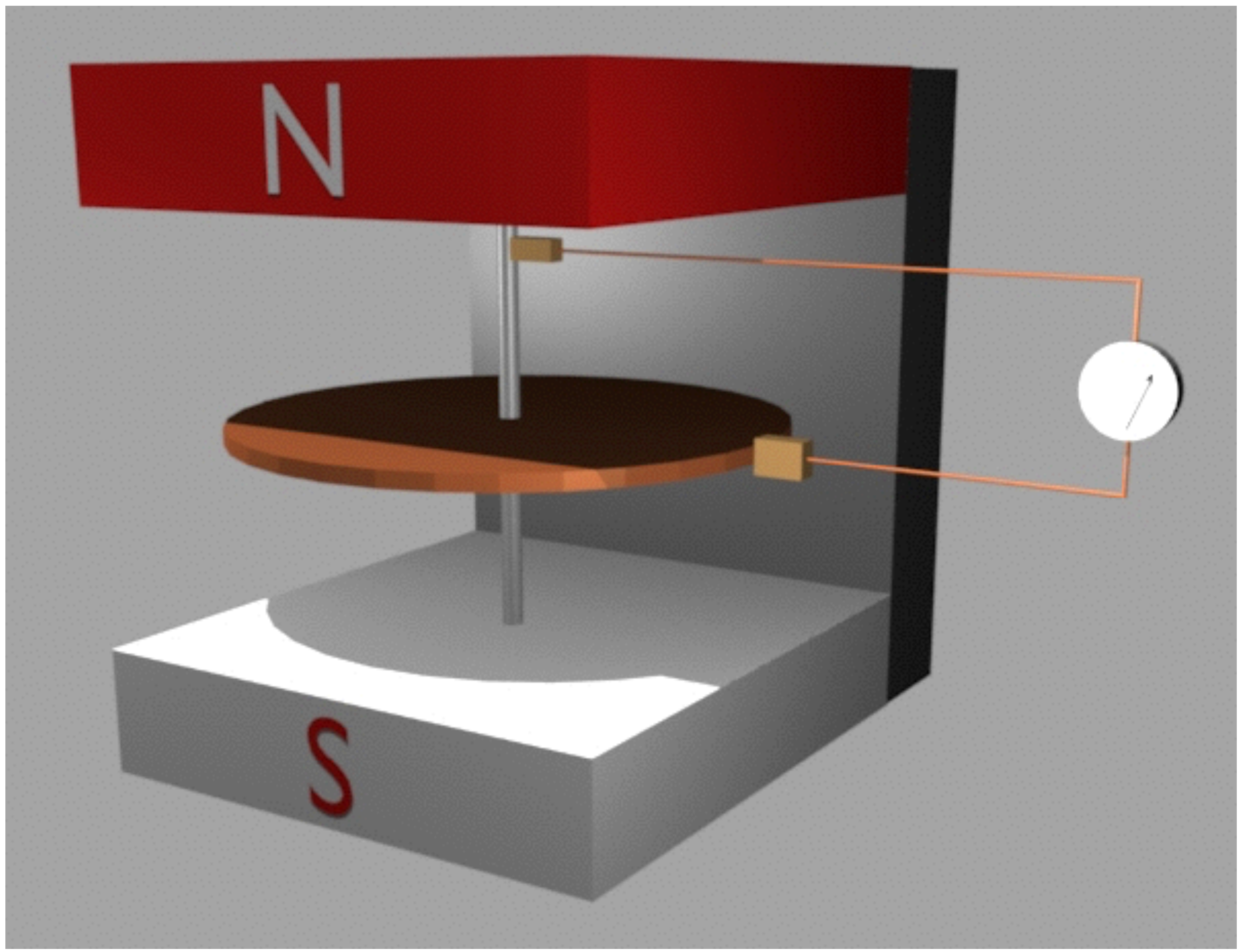
$$\mathcal{E} = -LvB$$

Demo: Is this EMF real?

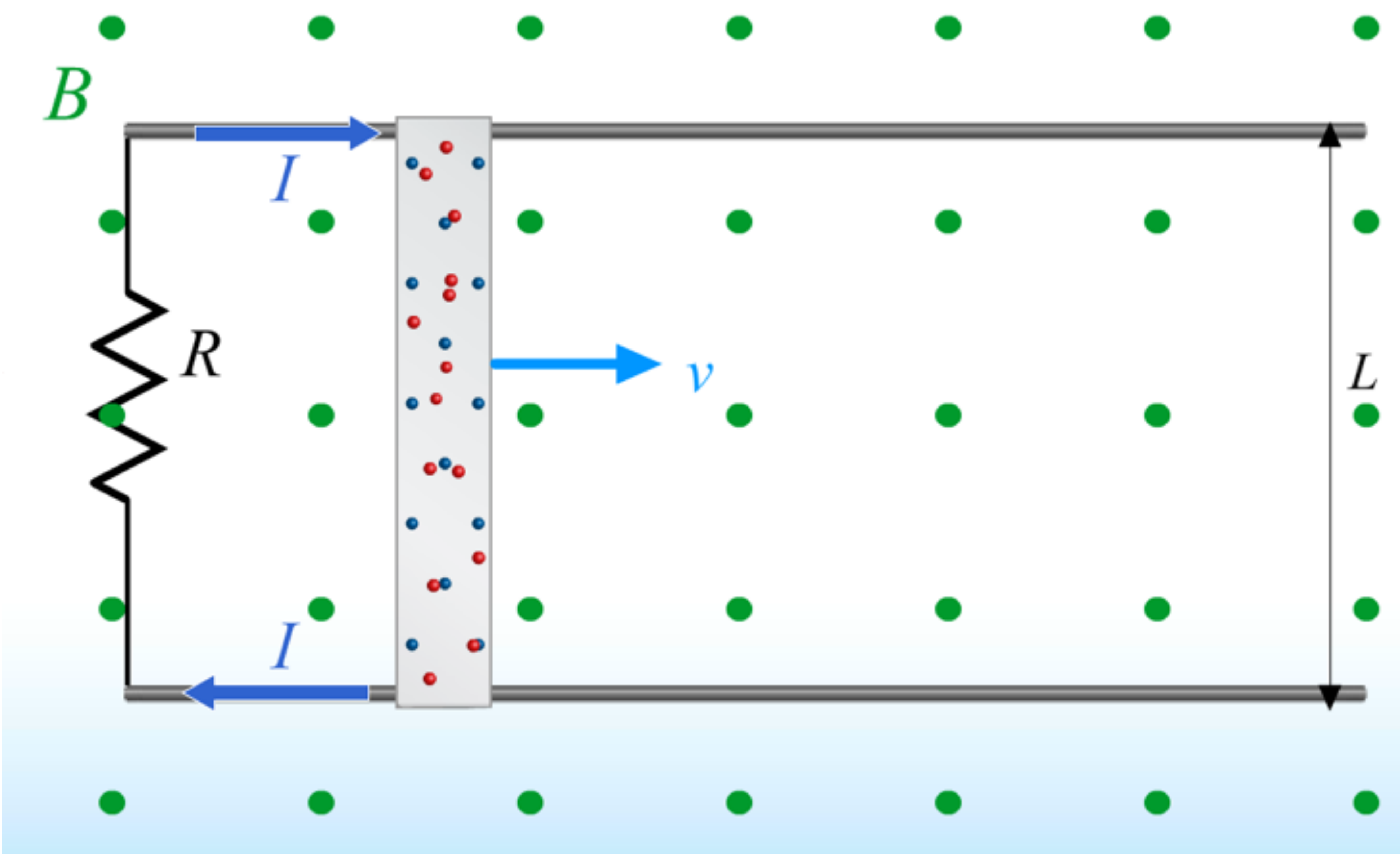


- Drives current I!

Question: Does the Faraday disk work as a motor?



Where does the energy come from?



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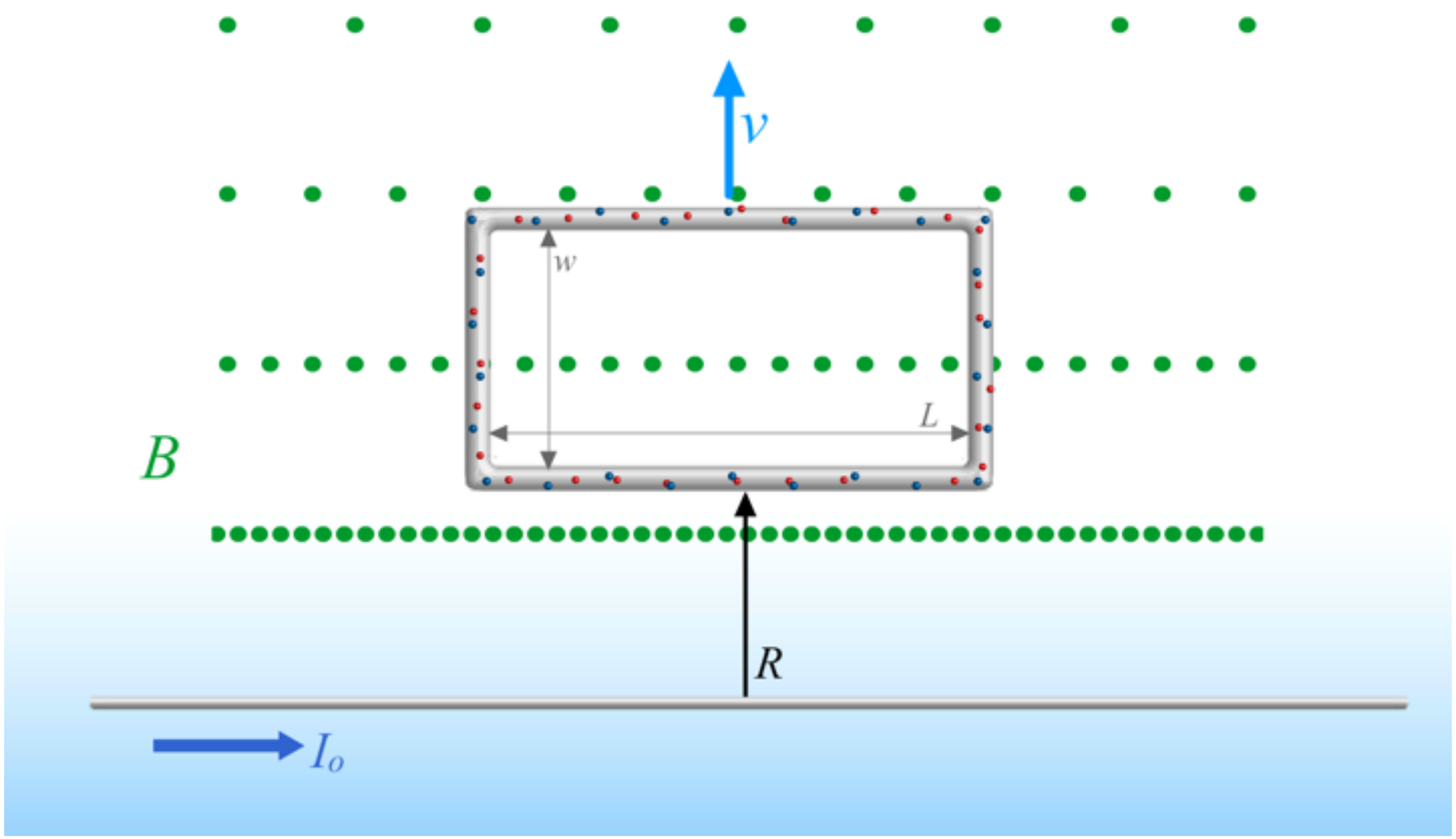
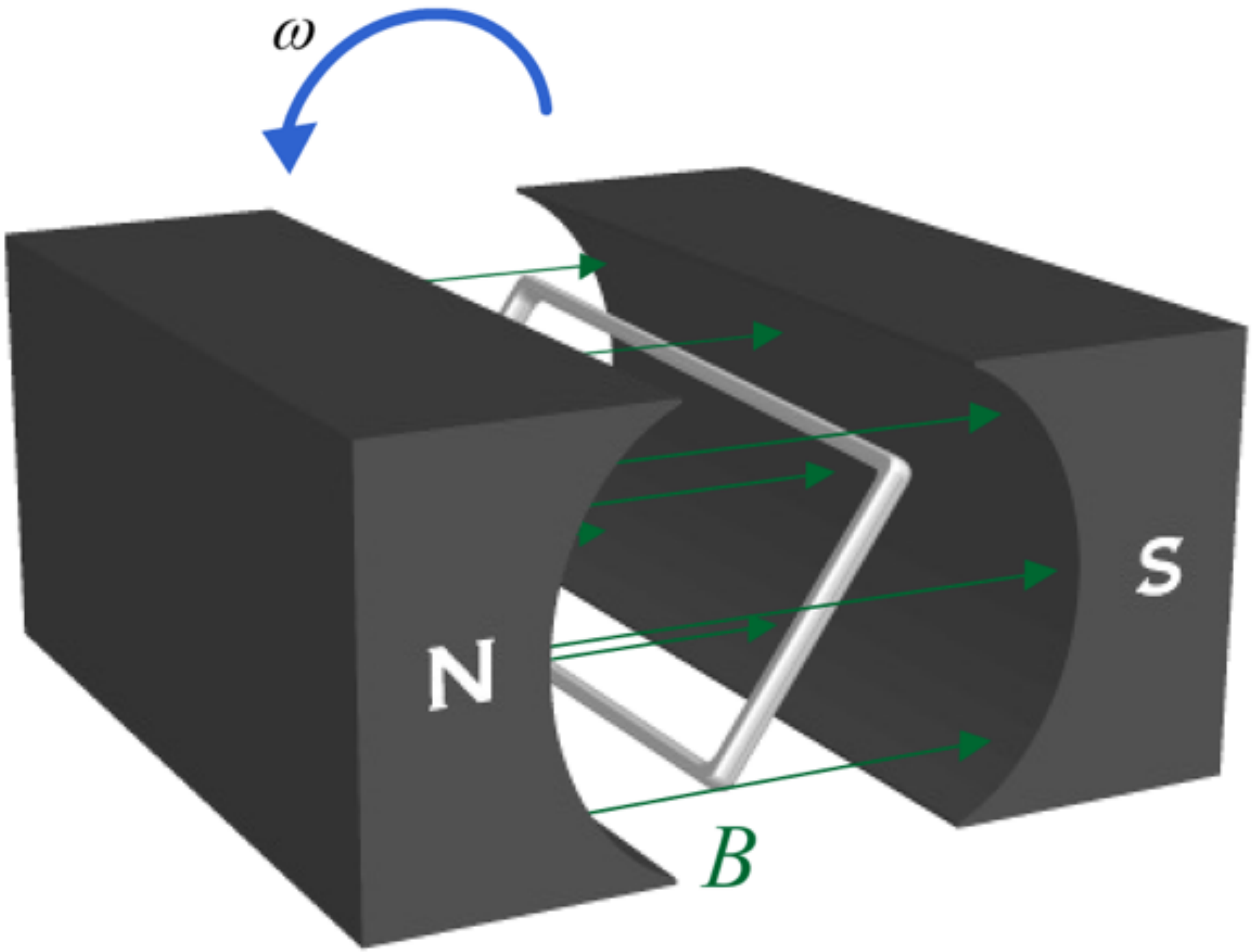
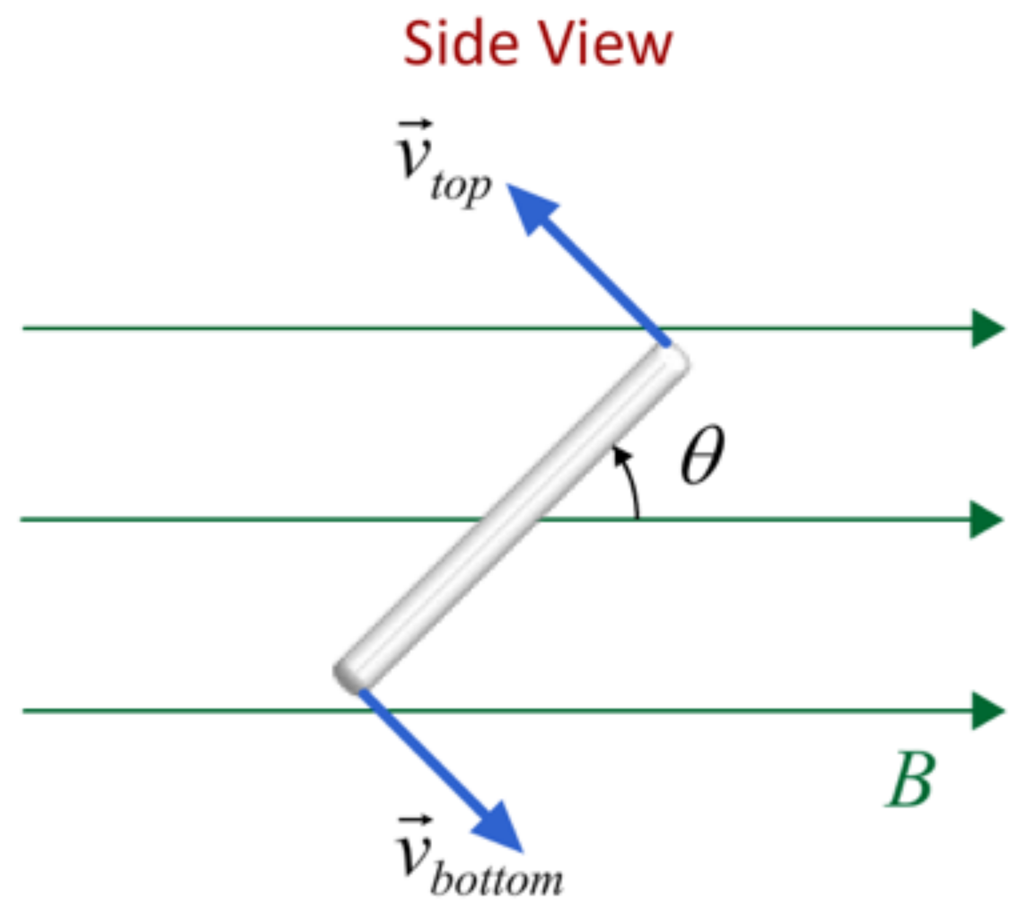
Another example…



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

Generator (Demo)





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

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