Announcements

- Phys 259 tutorial in ST 141 form 2:00-4:00 p.m. on Sunday April 9, 2017.

- Phys 259 tutorial in ST 143 form 2:00-4:00 p.m. on Saturday April 15, 2017.

Last time

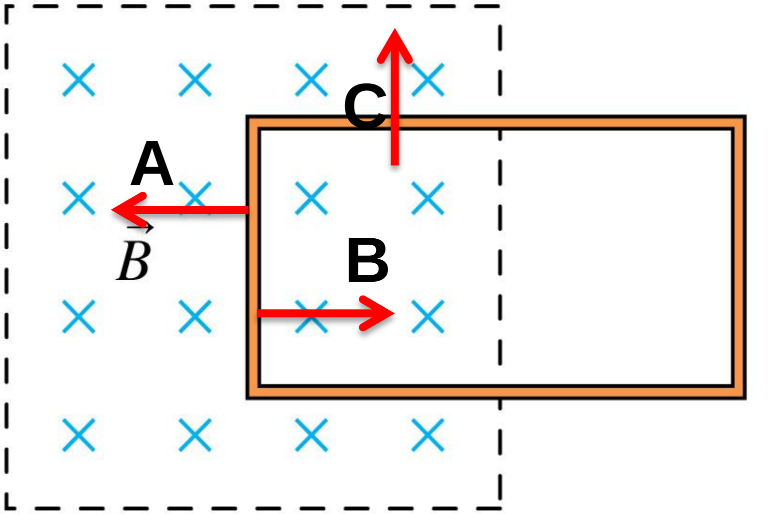
- Faraday’s law of induction
- Lenz’s law

This time

- AC generator
- DC generator
- Mutual inductance

Top Hat Question

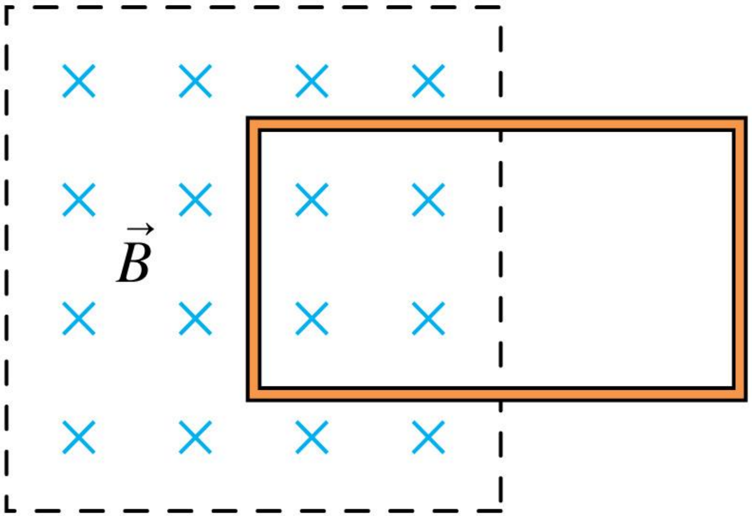
A conducting loop is halfway inside a magnetic field. Suppose the magnetic field begins to increase rapidly in strength. What happens to the loop?



A. The loop is pulled to the left, into the magnetic field.
B. The loop is pushed to the right, out of the magnetic field.
C. The loop is pushed upward, out of the magnetic field
D. The tension in the wire increases but the loop does not move.

Top Hat Question Feedback

A conducting loop is halfway inside a magnetic field. Suppose the magnetic field begins to increase rapidly in strength. What happens to the loop?

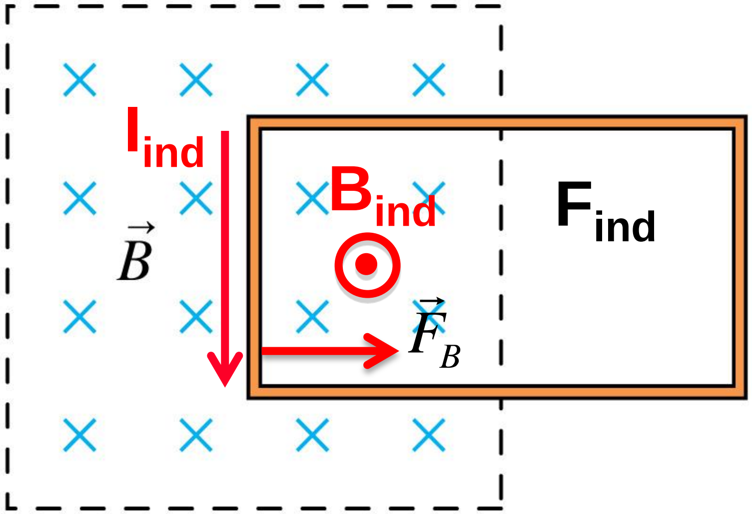


Qualitative argument

Lenz's Law: whatever happens must be such that it maintains the "amount of B-field" inside the loop. Since the strength of B is increasing, the loop must be pushed outside so that there are fewer B-field lines inside the loop.

Top Hat Question Feedback

A conducting loop is halfway inside a magnetic field. Suppose the magnetic field begins to increase rapidly in strength. What happens to the loop?



More rigorous argument

Lenz's Law: B_{ind} must point out, so I_{ind} is CCW

Recall: the Lorentz force on a current carrying wire

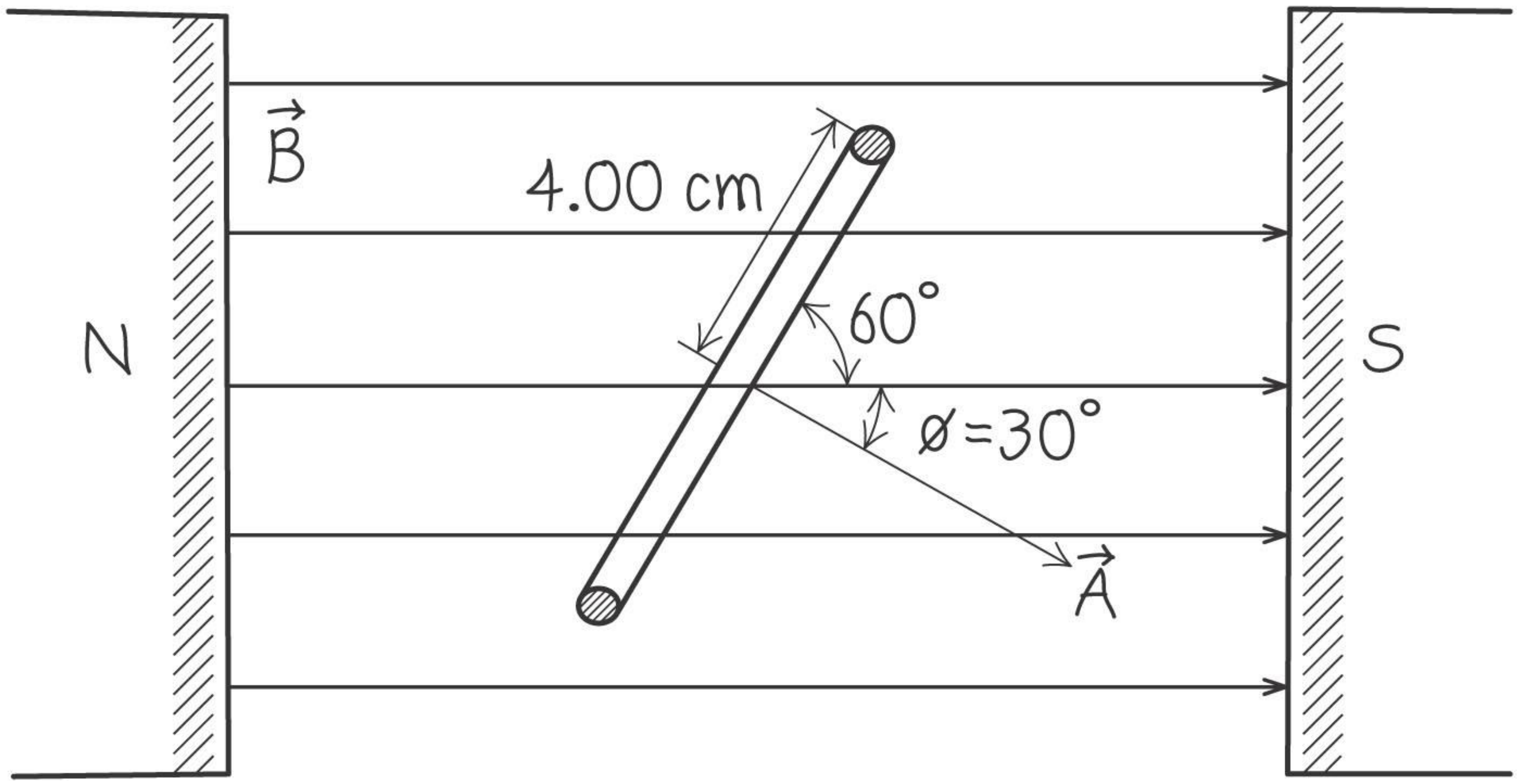
$$\vec{F}_B = I\vec{\ell} \times \vec{B} \;\Rightarrow\; \text{points to the RIGHT}$$

Faraday's Law of induction

$N = 500$

$R = 4.00\text{ cm}$

$$\frac{dB}{dt} = -0.200\text{ T/s}$$



$$\varepsilon = -\frac{d\Phi_M}{dt} = -\frac{d}{dt}(BA\cos\phi)$$

$$\varepsilon = -\frac{d\Phi_M}{dt} = -\frac{dB}{dt}A\cos\phi$$

$$\varepsilon = -N\frac{d\Phi_M}{dt} = -N\frac{dB}{dt}A\cos\phi$$

$$\varepsilon = -500\left(-0.200 \text{ T/s}\right)(0.00503 \text{ m}^2)\cos 30 = 0.435 \text{ V}$$

Curl your fingers around the area vector with your thumb in the direction of the area vector. Since the induced emf in the circuit is positive, it is in the same direction as your curled fingers

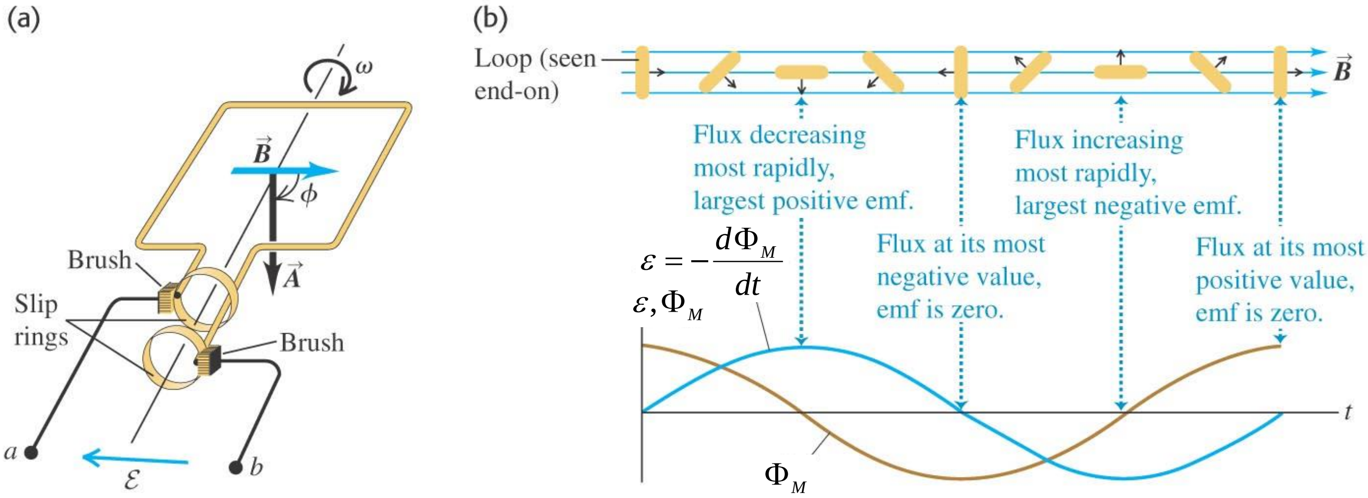
AC generator

$$\frac{d\Phi_M}{dt} = \frac{d\left(NBA\cos\phi\right)}{dt} = NBA\frac{d\cos\phi}{dt}$$

$$\phi = \omega t$$

$$\Phi_M = NBA\cos\omega t$$

$$\varepsilon = -\frac{d\Phi_M}{dt} = NBA\omega\sin\omega t$$

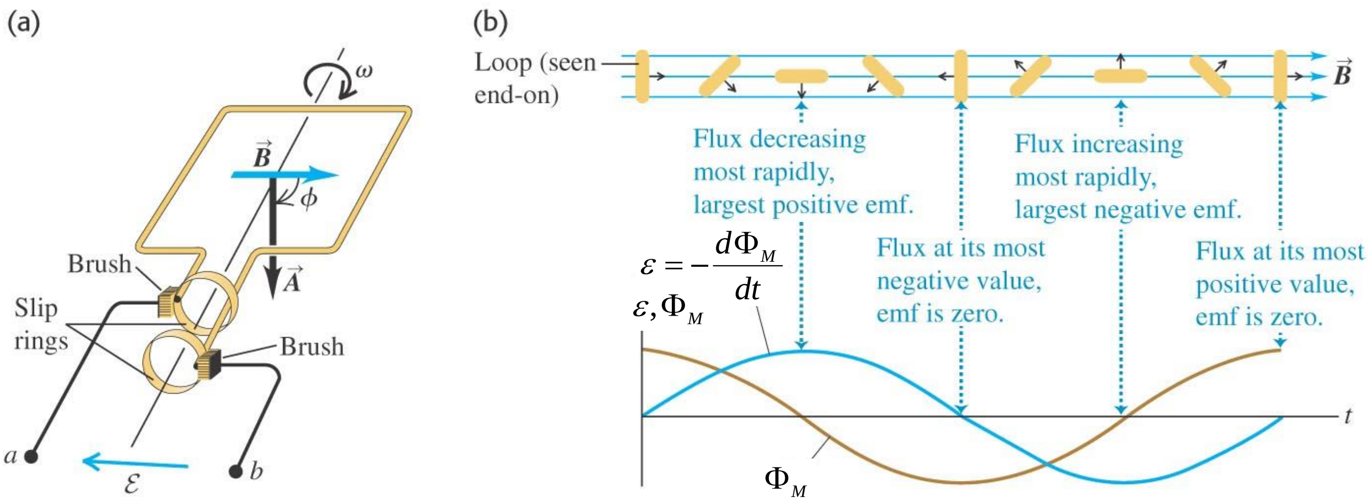


AC generator example

We see that emf is directly proportional to the magnetic field and rate of rotation of the loop. Such a device can be used to measure rotational speed or the magnetic field.

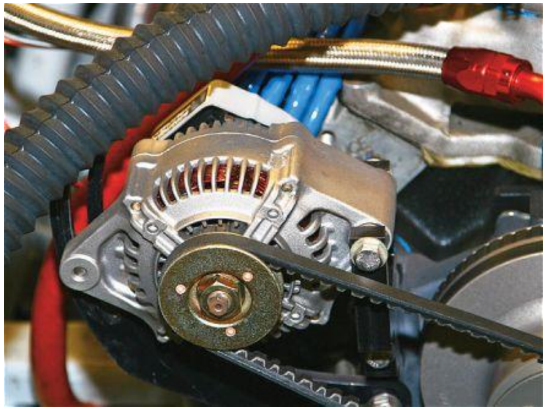
$$\Phi_M = NBA\cos\omega t$$

$$\varepsilon = -\frac{d\Phi_M}{dt} = NBA\omega\sin\omega t$$



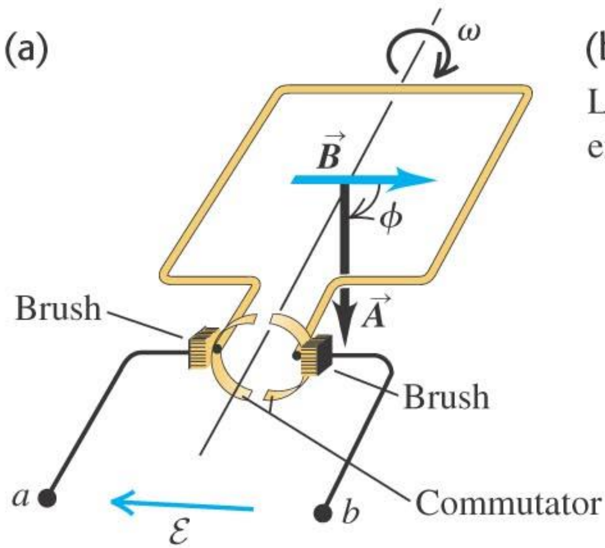
$$I(t) = \frac{\varepsilon}{R} = \frac{NBA\omega}{R}\sin\omega t$$

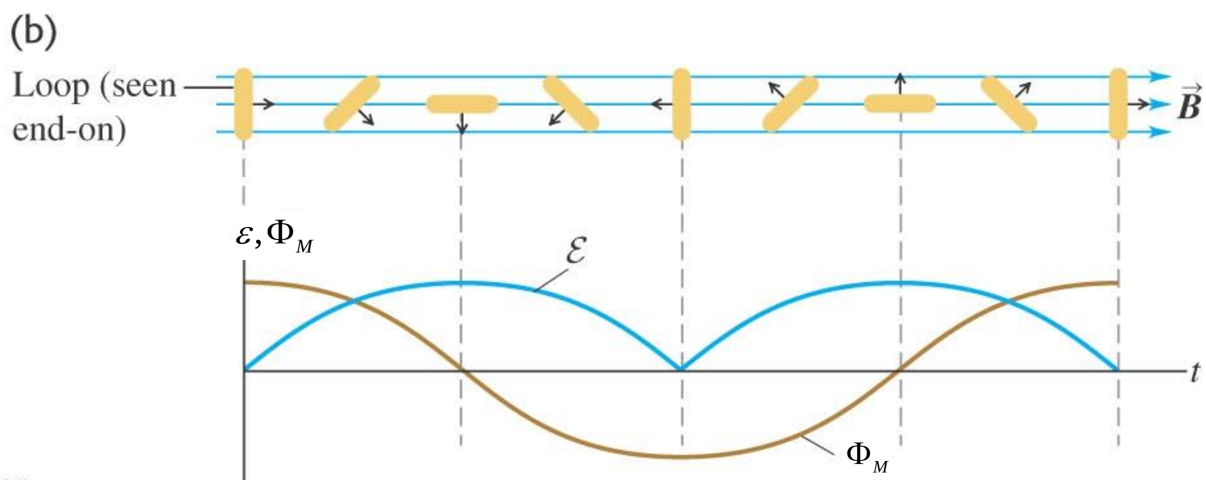
Generates alternating current (ac generator).
Alternators are used in cars to generate currents in the ignition, the lights, and entertainment systems.
Here the coil is stationary but the magnet is rotating.



DC generator

DC generator



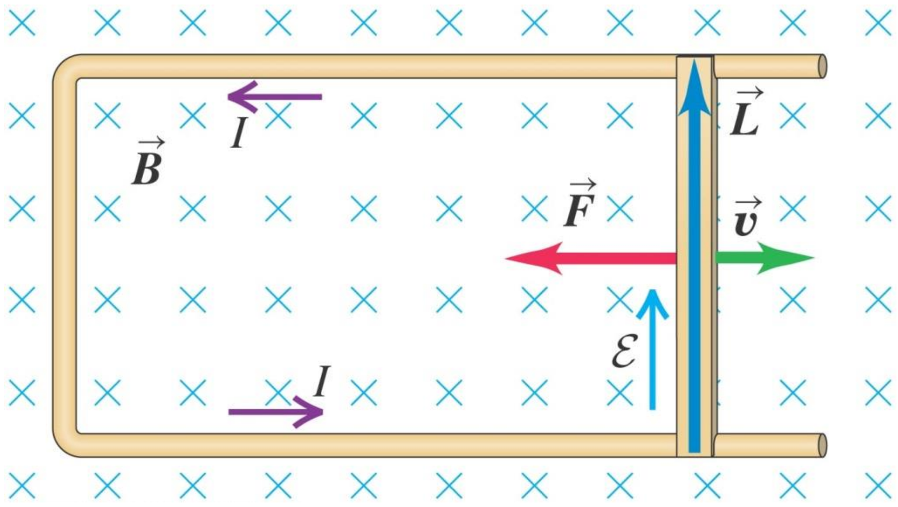


$$\left|\varepsilon\right| = NBA\omega\left|\sin\omega t\right| \qquad \left|\sin\omega t\right|_{\text{time average}} = \frac{\int_0^{T/2=\frac{\pi}{\omega}} \sin\omega t\,dt}{\pi/\omega} = \frac{2}{\pi}$$

$$\varepsilon_{\text{Av}} = \frac{2NBA\omega}{\pi} \qquad \omega = \frac{\pi\varepsilon_{\text{Av}}}{2NBA} = \frac{\pi(112\text{ V})}{2(500)(0.200\text{ T})(0.1\text{ m}^2)} = 176\text{ rad/s}$$

$$\omega = 176\text{ rad/s} = 176\text{ rad/s}\,\frac{1\text{ rev}}{2\pi\text{ rad}}\,\frac{60\text{ s}}{1\text{ min}} = 1680\text{ rev/min}$$

Work and power in a slide wire generator



$$I = \frac{|\varepsilon|}{R} = \frac{BLv}{R}$$

$$\vec{F} = I\vec{L} \times \vec{B}$$ To the left, opposes the motion

$$P_{dissipated} = I^2 R = \left(\frac{BLv}{R}\right)^2 R = \frac{B^2 L^2 v^2}{R}$$

$$F = I\ LB = \left(\frac{BLv}{R}\right) LB = \frac{B^2 L^2 v}{R}$$

$$P_{Applied} = Fv = \frac{B^2 L^2 v^2}{R}$$

$$P_{Applied} = P_{Dissipated}$$ Consrvation of energy