Physics II: 1702
Gravity, Electricity, & Magnetism

Professor Jasper Halekas
Van Allen 70 [Clicker Channel #18]
MWF 11:30-12:30 Lecture, Th 12:30-1:30 Discussion

Reminders

- Lab E8 (Faraday's Law) Tonight
- HW9 on Wiley Plus due Wednesday night

Faraday's Law

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

$$\oint_{Loop} \vec{E} \cdot d\vec{l} = -\frac{d}{dt} \int_{surf} \vec{B} \cdot d\vec{A}$$

Lenz's Law

The (-) negative sign in Faraday's Law is an important reminder.

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

Lenz's Law: The induced EMF tends to induce a current in the direction which opposes the changes in Magnetic Flux.

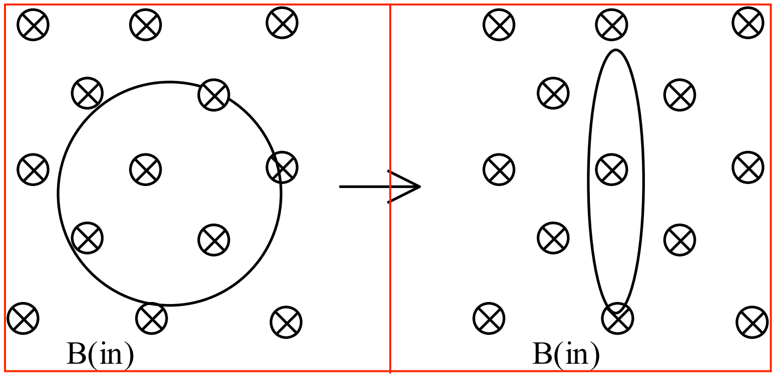
Concept Check

A loop of wire is sitting in a uniform, constant magnet field as shown. Suddenly, the loop is bent into a smaller area loop. During the bending of the loop, the induced current in the loop is ...

A: zero

B: clockwise

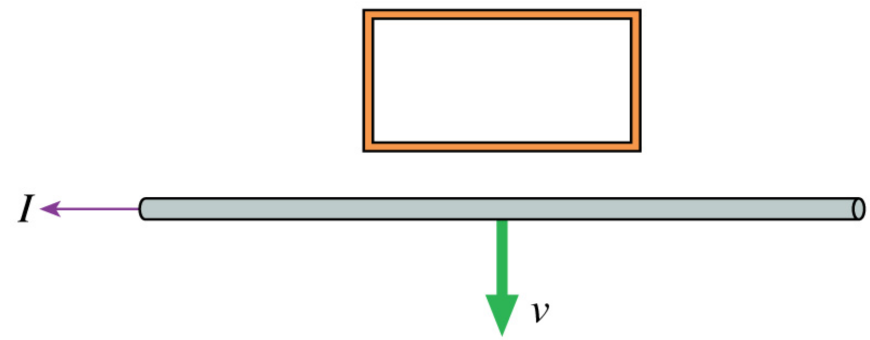
C: counterclockwise



Answer: Clockwise. The flux into the page is *decreasing* as the loop area decreases. To fight the decrease, we want the induced B to *add* to the original B. By the right hand rule (version II) , a clockwise induced current will make an induced B into the page, adding to the original B.

Concept Check

A current-carrying wire is pulled away from a conducting loop in the direction shown. As the wire is moving, is there a clockwise current around the loop, a counterclockwise current or no current?

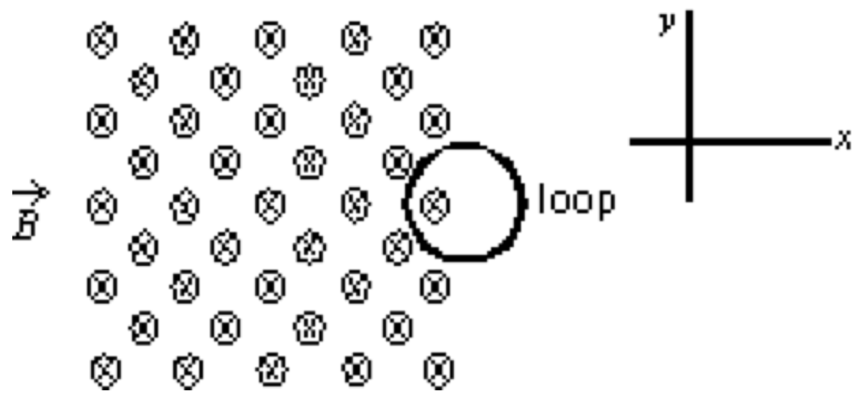


A. There is a clockwise current around the loop.
B. There is a counterclockwise current around the loop.
C. There is no current around the loop.

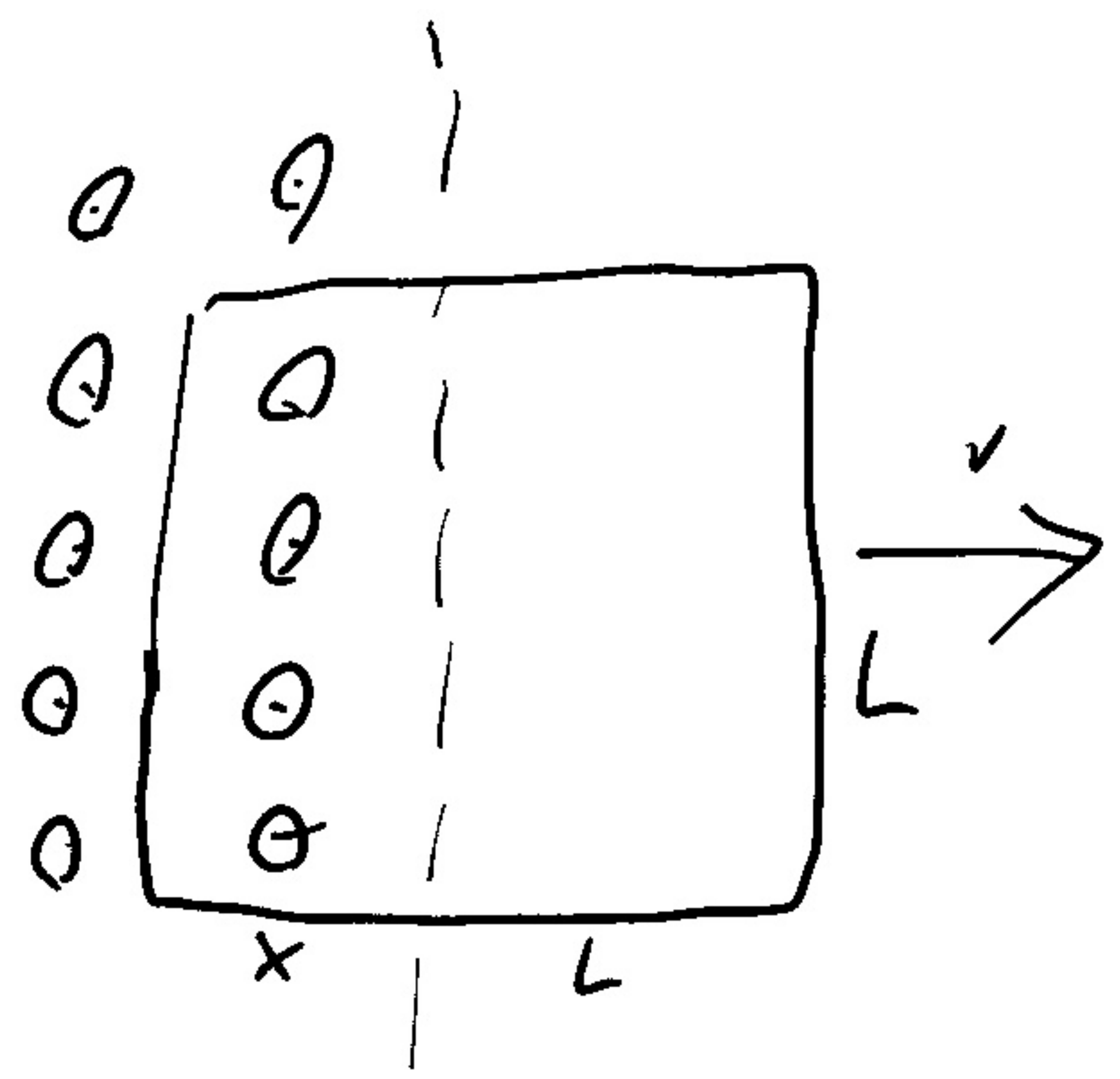
Concept Check

Q9) A circular loop of wire is positioned half in and half out of a square region of constant uniform magnetic field directed into the page, as shown below. To induce a clockwise current in the loop:

1) move it in the +x direction
2) move it in the -x direction
3) move it in the +y direction
4) move it in the -y direction
5) two of the above



- pulling wire loop out of field



wire has total resistance R

$$\varphi_B = B \cdot A_{overlap}$$
$$= BLx$$

$$d\varphi_B/dt = d/dt\,(BLx)$$
$$= BL\,dx/dt$$
$$= BLv$$

$$\mathcal{E} = -BLv = iR$$ through wire

$\Rightarrow i = BLv/R$

φ decreasing so i ccw to oppose

– What is magnetic force on loop?

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

$$= ILB \text{ to left}$$

$$= \frac{BLv}{R} \cdot LB$$

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

$$P = \frac{dW}{dt} = \frac{d}{dt}(F \cdot x)$$

$$= F \cdot v$$

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

P dissipated in resistor

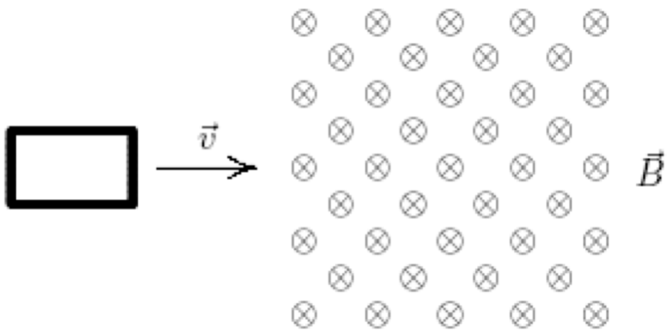
$$= i^2R$$

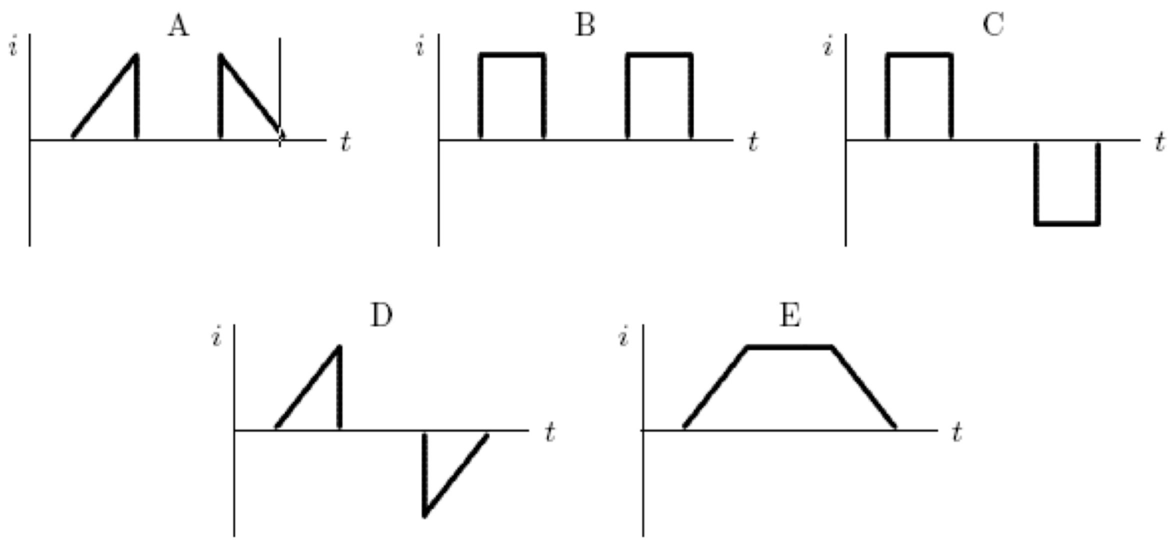
$$= \left(\frac{BLv}{R}\right)^2 R = \frac{B^2L^2v^2}{R}$$

All power expended to pull loop dissipated in resistor.

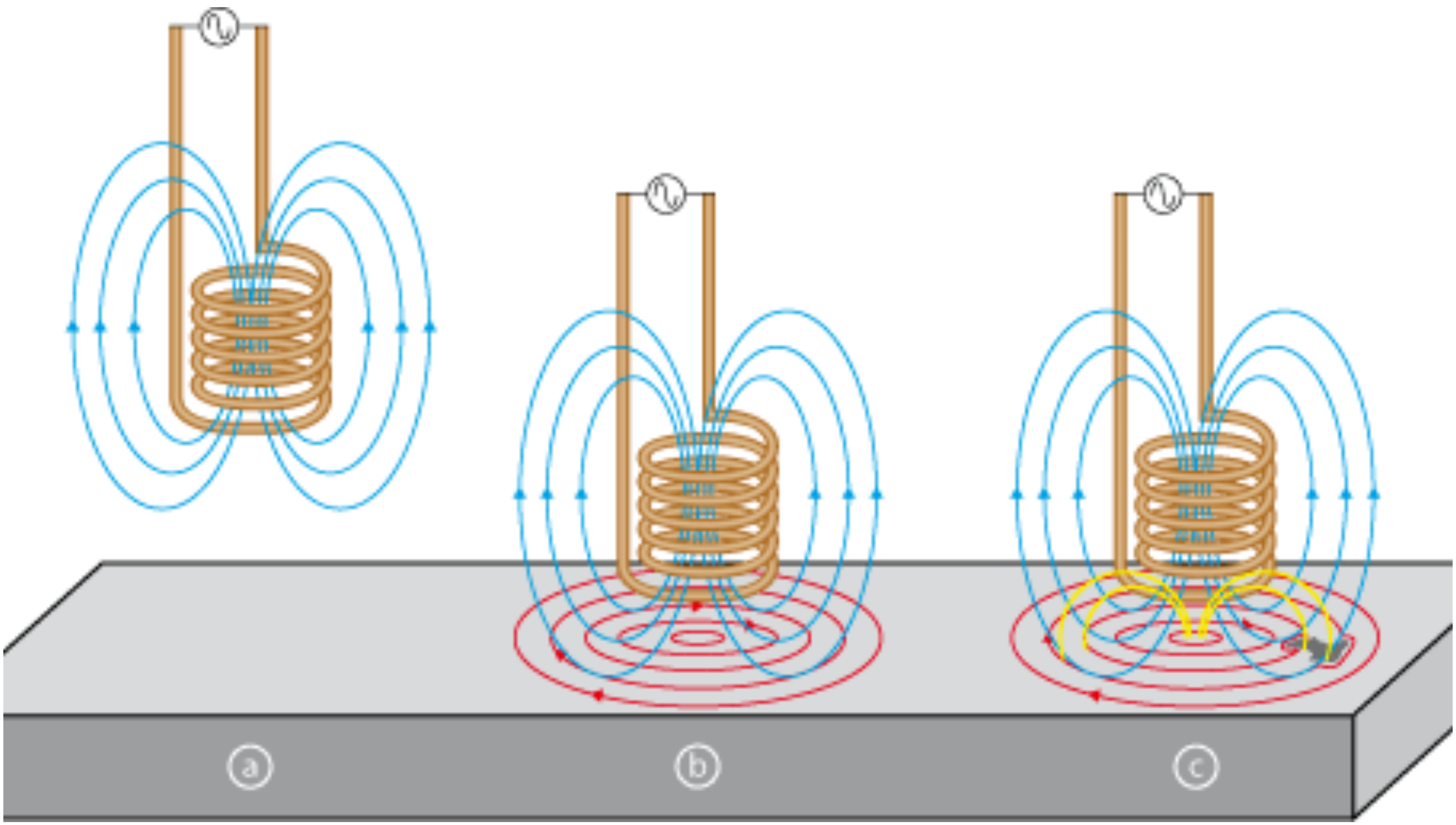
Concept Check

Q31) A square loop of wire moves with a constant speed v from a field-free region into a region of constant uniform magnetic field, as shown. Which of the five graphs correctly shows the induced current i in the loop as a function of time t?

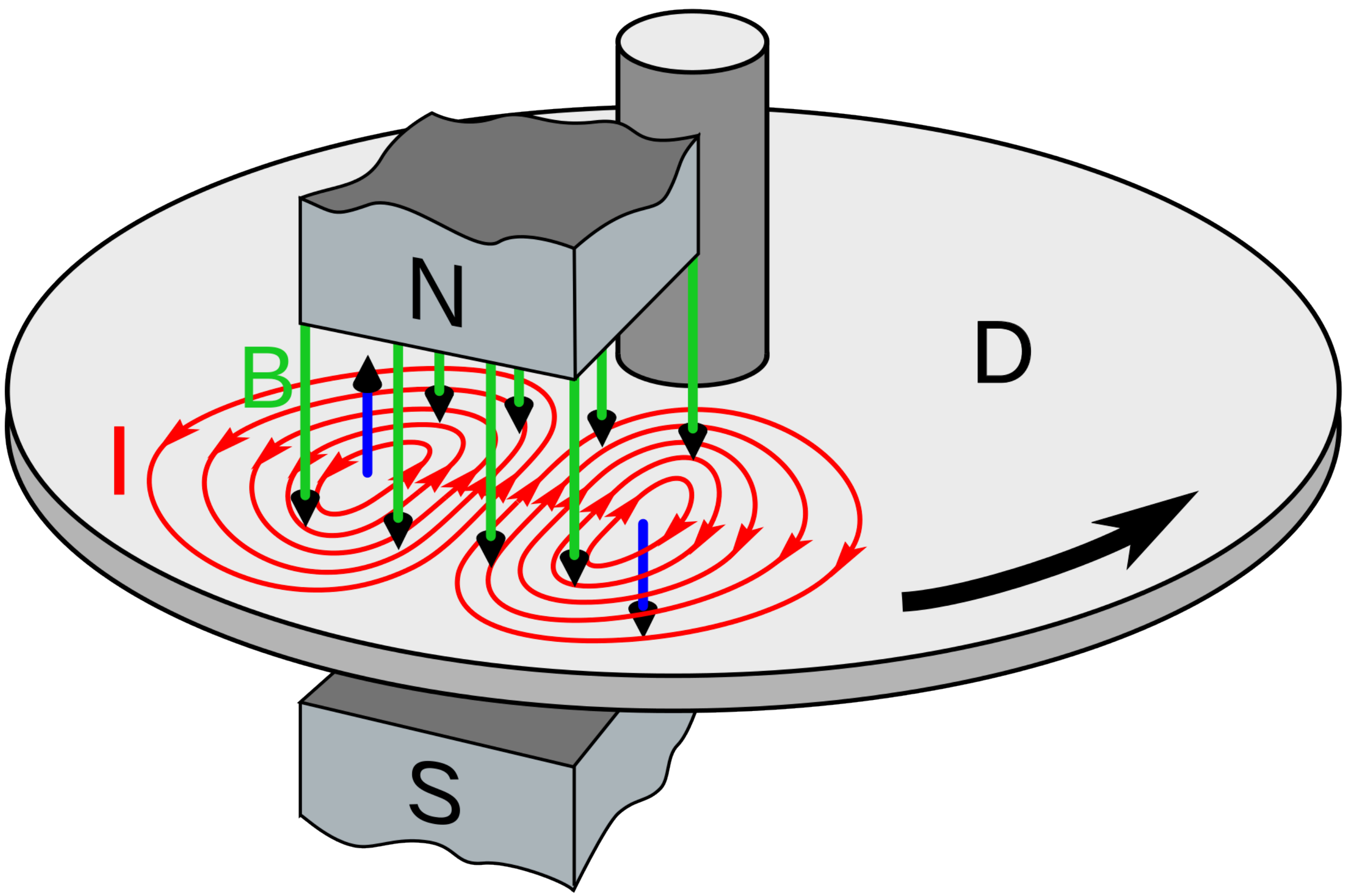




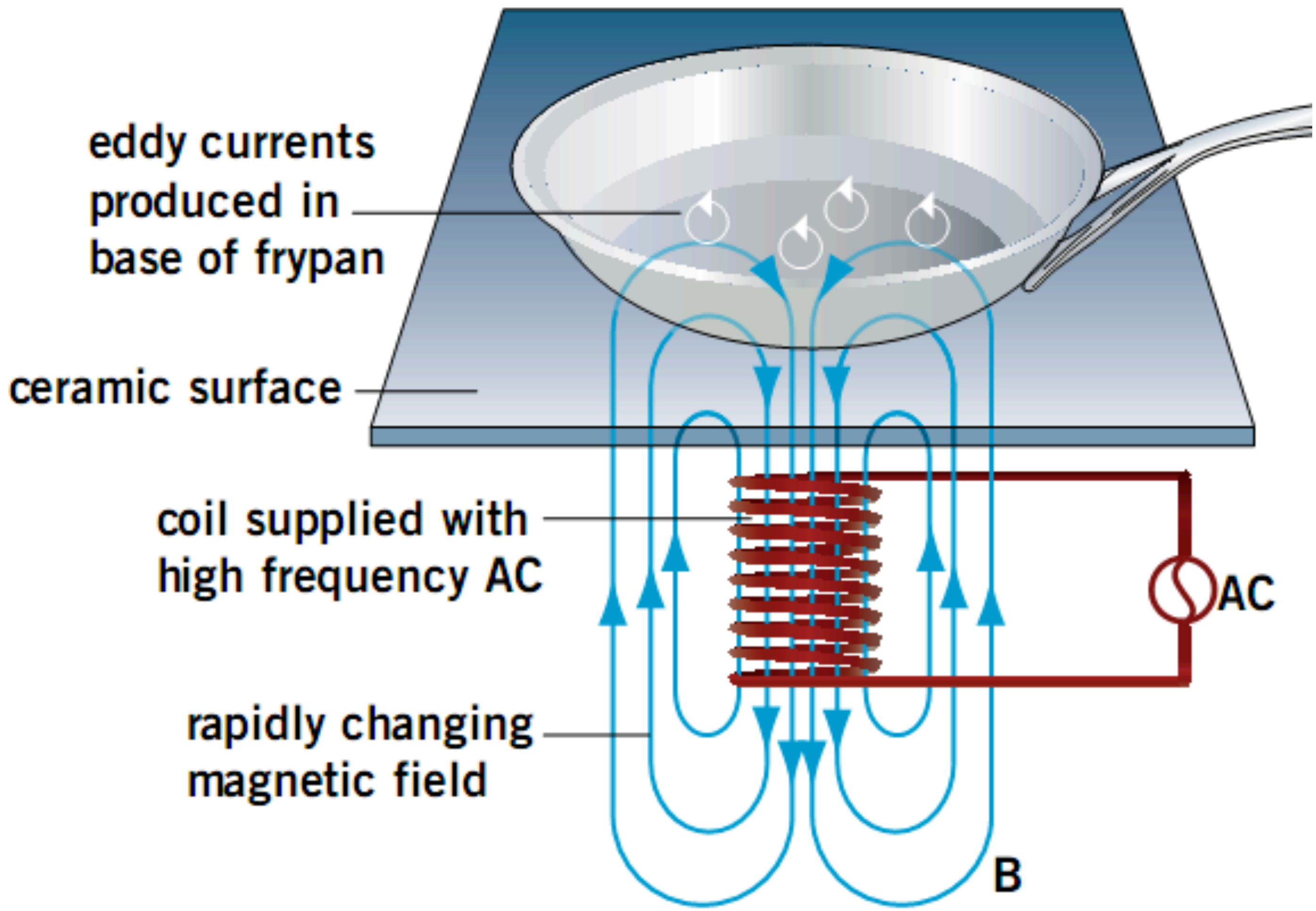
Eddy Currents



Eddy Current Brake



Inductive Heating



Inductors

Self-Inductance (L) of a coil of wire

$$\Phi_B \equiv Li$$

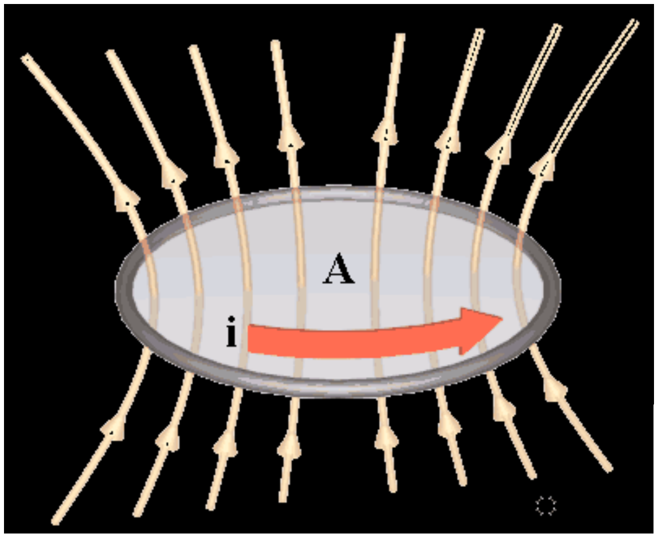
$$L \equiv \frac{\Phi_B}{i}$$

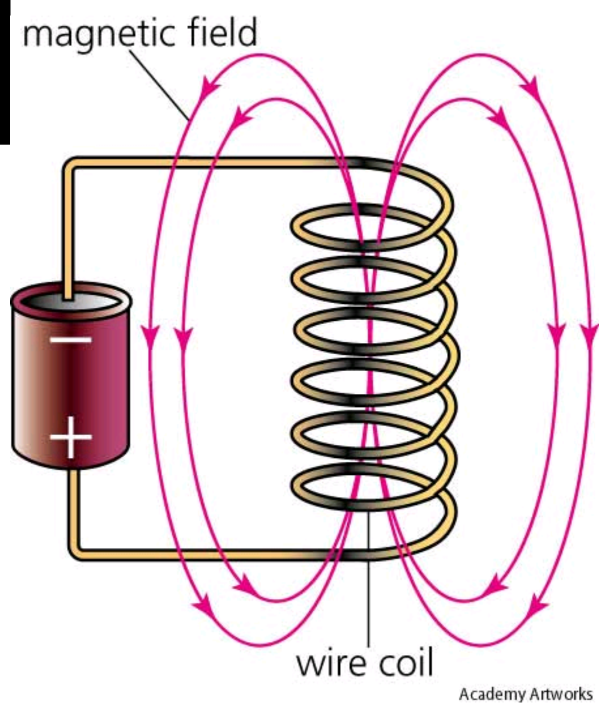
This equation defines self-inductance.

Note that since $\Phi_B \alpha$ i, L must be independent of the current i.

L has units [L] = [Tesla meter^2]/[Amperes]
New unit for inductance = [Henry].

Inductors





Inductance of Solenoid

$$B = \mu_0 I N / l$$

$\varphi_{B_L} = B \cdot A$ for each loop

$\varphi_{B\,total} = N \varphi_{B_L} = NBA$

$$L = \varphi_B / I = NBA / I$$

$$L = N \cdot \mu_0 I N / l \cdot A / I$$

$$= N^2 \mu_0 A / l$$

write w/ $n = N/l$
(turns per length)

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

or $L/l = n^2 \mu_0 A$

Inductance goes up as square of turns

Inductance

What does inductance tell us?

$$L = \frac{\Phi_B}{i}$$

$$\Phi_B = Li$$

$$\frac{d\Phi_B}{dt} = L\frac{di}{dt}$$

L is independent of time.
Depends only on geometry of inductor (like capacitance).

Inductor Effect in Circuit

$$\frac{d\Phi_B}{dt} = L\frac{di}{dt}$$

Recall Faraday's Law

$$\varepsilon = -\frac{d\Phi_B}{dt}$$

$$-\varepsilon = L\frac{di}{dt}$$

$$\varepsilon = -L\frac{di}{dt}$$

Changing the current in an inductor creates an EMF which opposes the change in the current. Sometimes called "back EMF"