Inductors

Session 2b of “Basic Electricity”
A Fairfield University E-Course
Powered by LearnLinc

Basic Electricity

Two Sections

- Electron Flow and Resistance
  - 5 on-line sessions
  - Lab
- Inductance and Capacitance
  - 5 on-line sessions
  - Lab

Mastery Test, Part 1

Basic Electricity (Continued)

- Text: "Electricity One-Seven," Harry Mileaf, Prentice-Hall, 1996, ISBN 0-13-889585-6 (Covers several Modules and more)
- References:
  - "Digital Mini Test: Principles of Electricity Lessons One and Two," SNET Home Study Coordinator, (203) 771-5400
  - Electronics Tutorial (Thanks to Alex Pounds)
  - Electronics Tutorial (Thanks to Mark Sokos)
  - Basic Math Tutorial (Thanks to George Mason University)
  - Vector Math Tutorial (Thanks to California Polytec at atom.physics.calpoly.edu)

Section 2: AC, Inductors and Capacitors

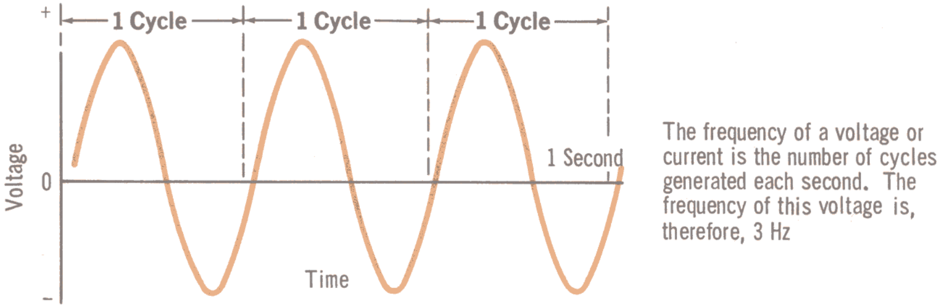
- 0BJECTIVES: This section introduces AC voltage / current and additional circuit components (inductors, transformers and capacitors).

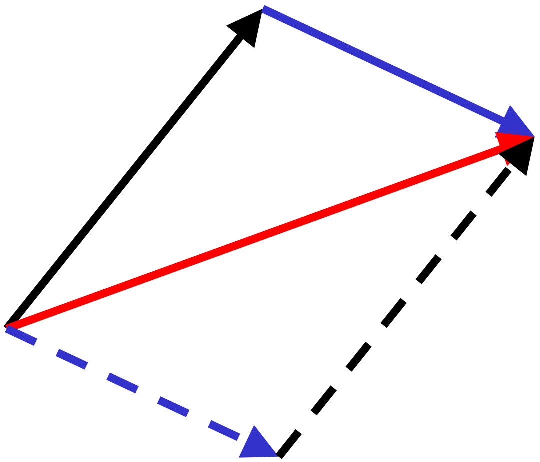
Section 2 Schedule:

Session 2a – 03/27	Alternating Current & Sine Waves	Text 3.1 – 3.41
Vector Math – 04/01	Sine Waves, Magnitude, Phase and Vectors	Text 4.1 – 4.24
Session 2b – 04/03 (fri. review session?)	**Inductors and Circuits**	**Text 3.42 – 3.73**
Session 2c – 04/08	Transformers	Text 3.74 – 3.100
Session 2d – 04/10 (lab - 04/13, Sat.)	Capacitors	Text 3.101 – 3.135
Session 2e – 04/15	More Capacitors	Text 3.135 – 3.148
Session 2f – 04/22	Review (Discuss Quiz_2)	

Vector Session Review

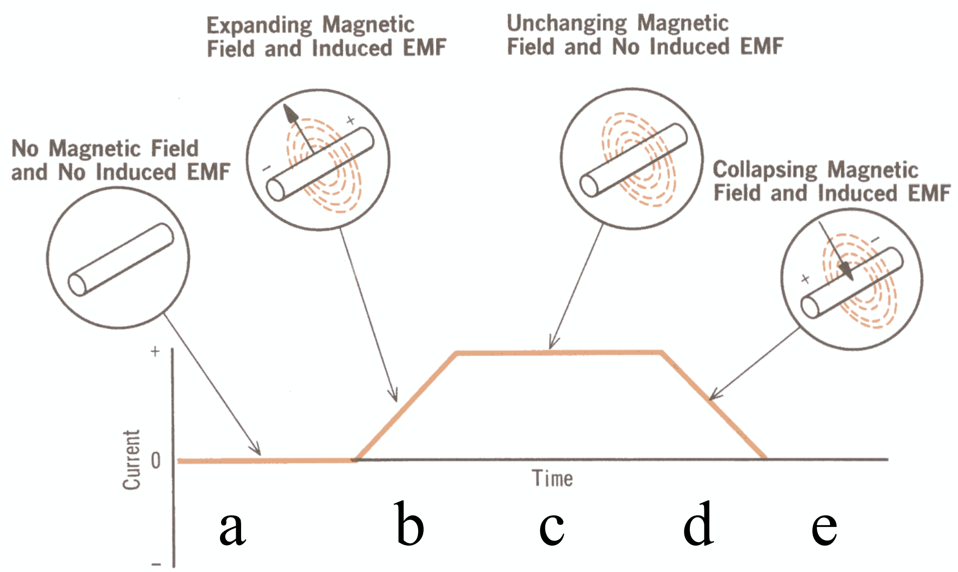
- Sine waves – sin(2πft+θ)
  - Frequency (f)
    - Period & Wavelength (λ)
  - Amplitude (A)
  - Phase (θ)
    - Sin and Cos
    - Adding sine waves
- Vector analogy
  - Magnitude and Angle
  - Addition
    - Head-to-Tail
    - Parallelogram
    - Components (Later)





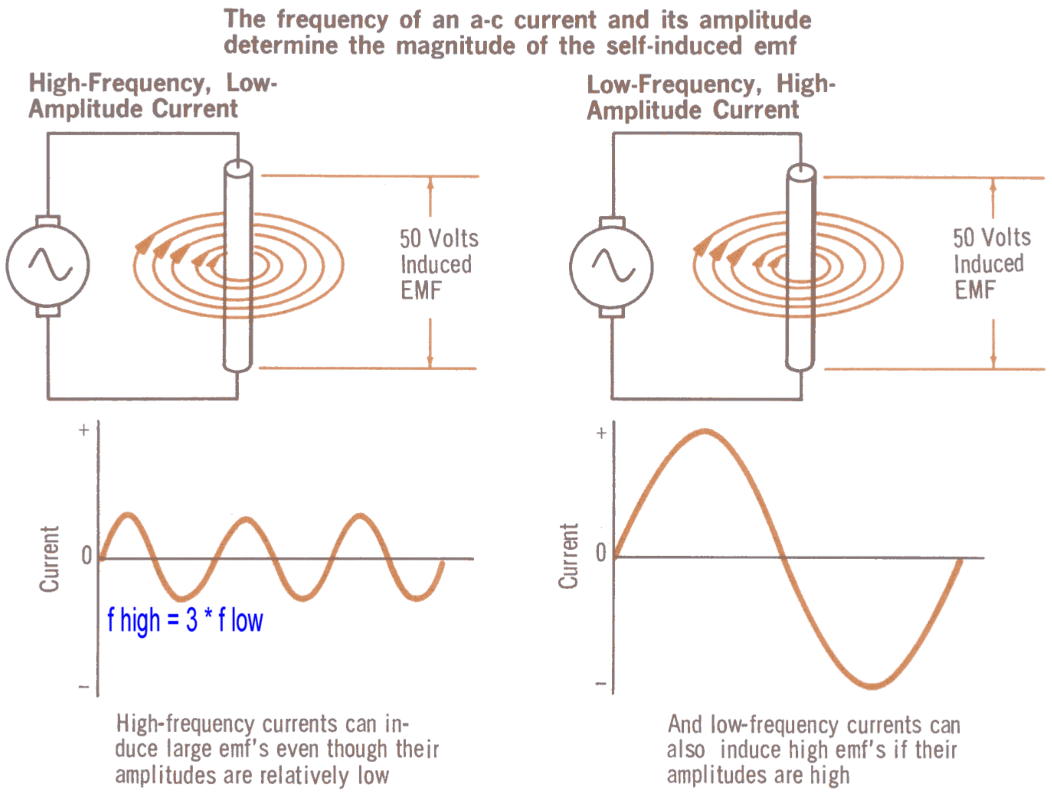
EMF and Current

a. No applied voltage;
   no current
b. Constant applied voltage;
   linearly increasing current
c. Zero applied voltage;
   unchanging current
d. Negative applied voltage;
   linearly decreasing current
e. no applied voltage;
   no current



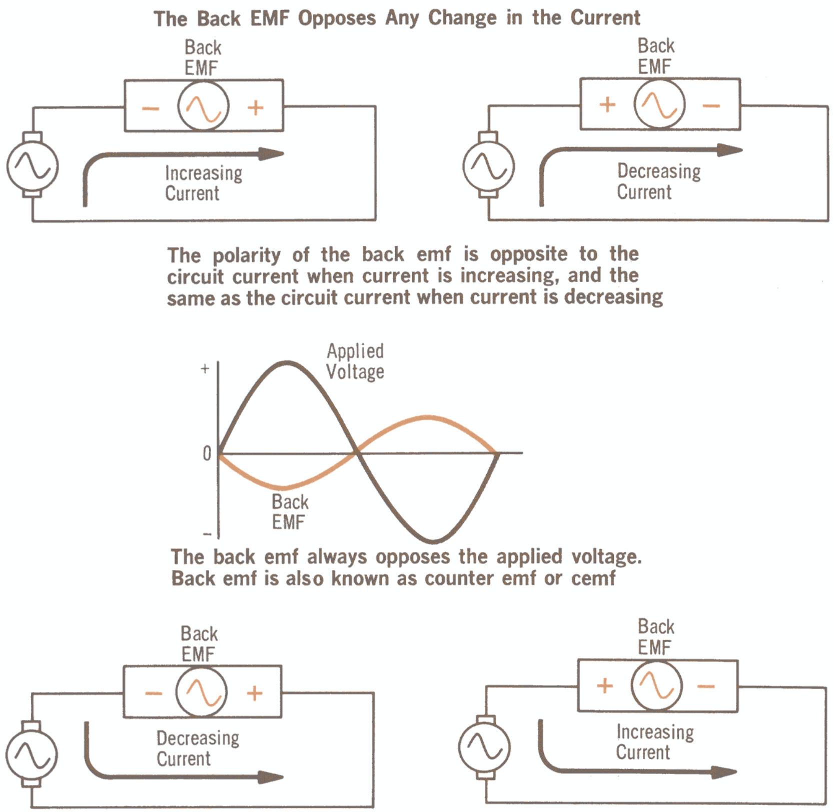
Frequency Effects

- To get the same effect from low frequency AC current, you need a higher current



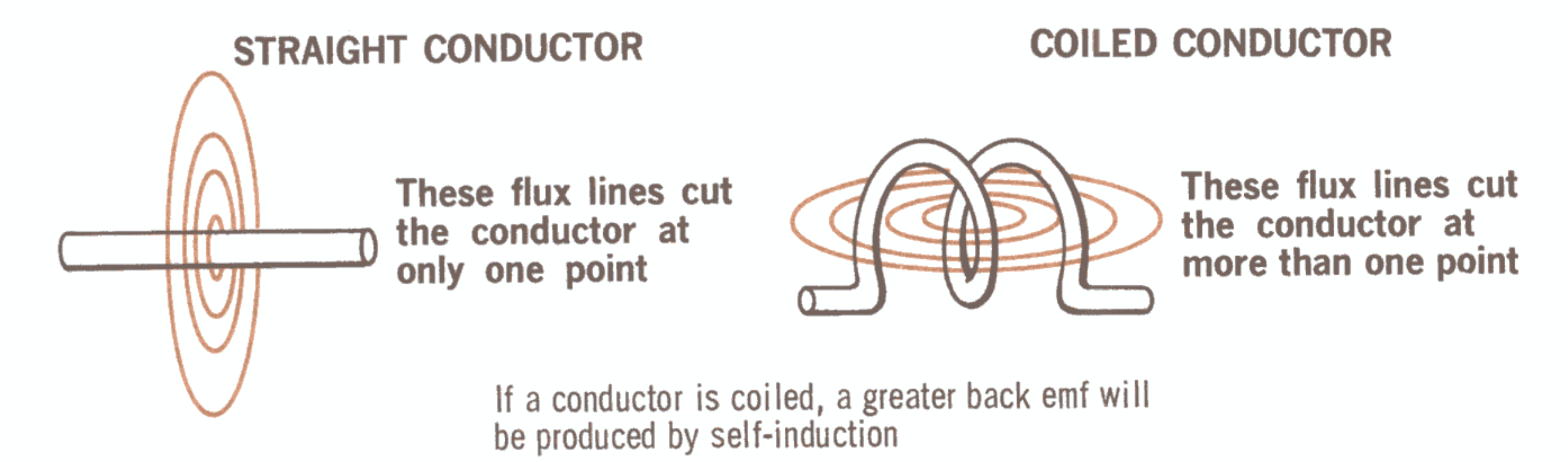
EMF Polarity vs. Applied Voltage

- Induced EMF always opposes voltage applied across the inductor



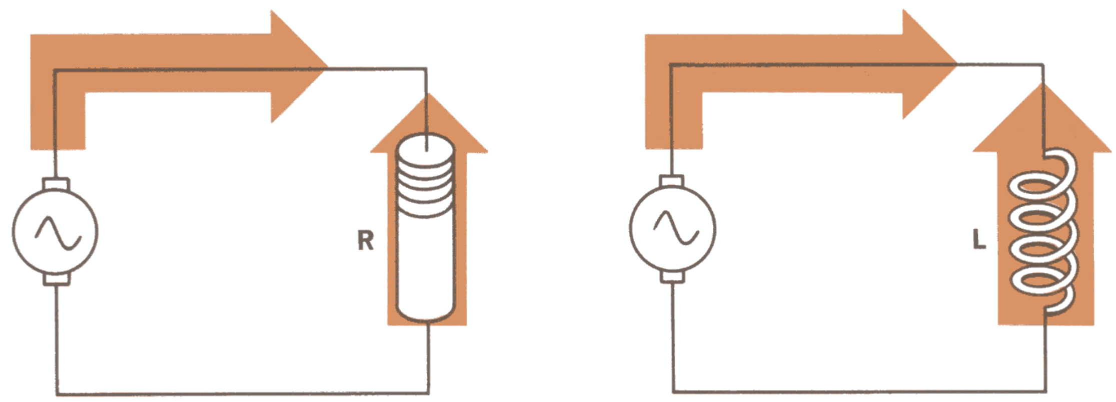
Coiling to Increase Inductance

- Coiling a wire increases its inductance
- Magnetic fields from each loop support each other ("mutual inductance")



Resistors vs. Inductors

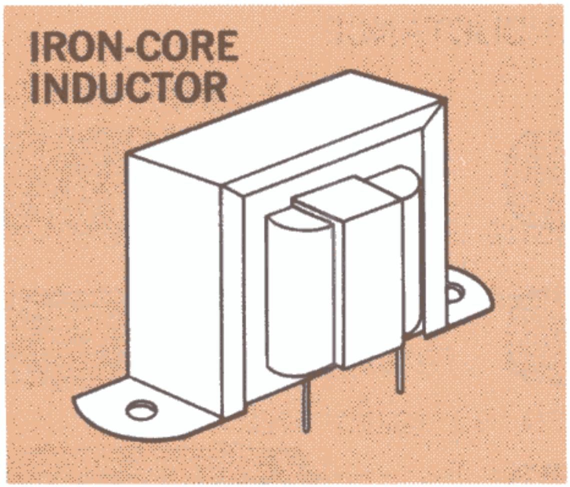
- Analogy to Ohm's law for resistors
- Inductors resist changes in their current with their "Reactance"

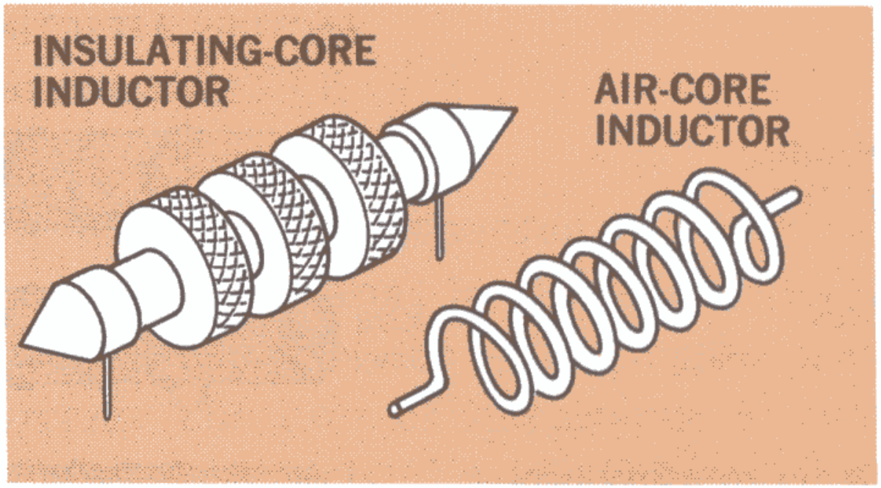


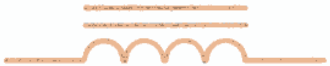
Resistors oppose all current in a circuit. They have resistance, which is abbreviated R

Inductors oppose changes in current in a circuit. They have inductance, which is abbreviated L

Real Inductors



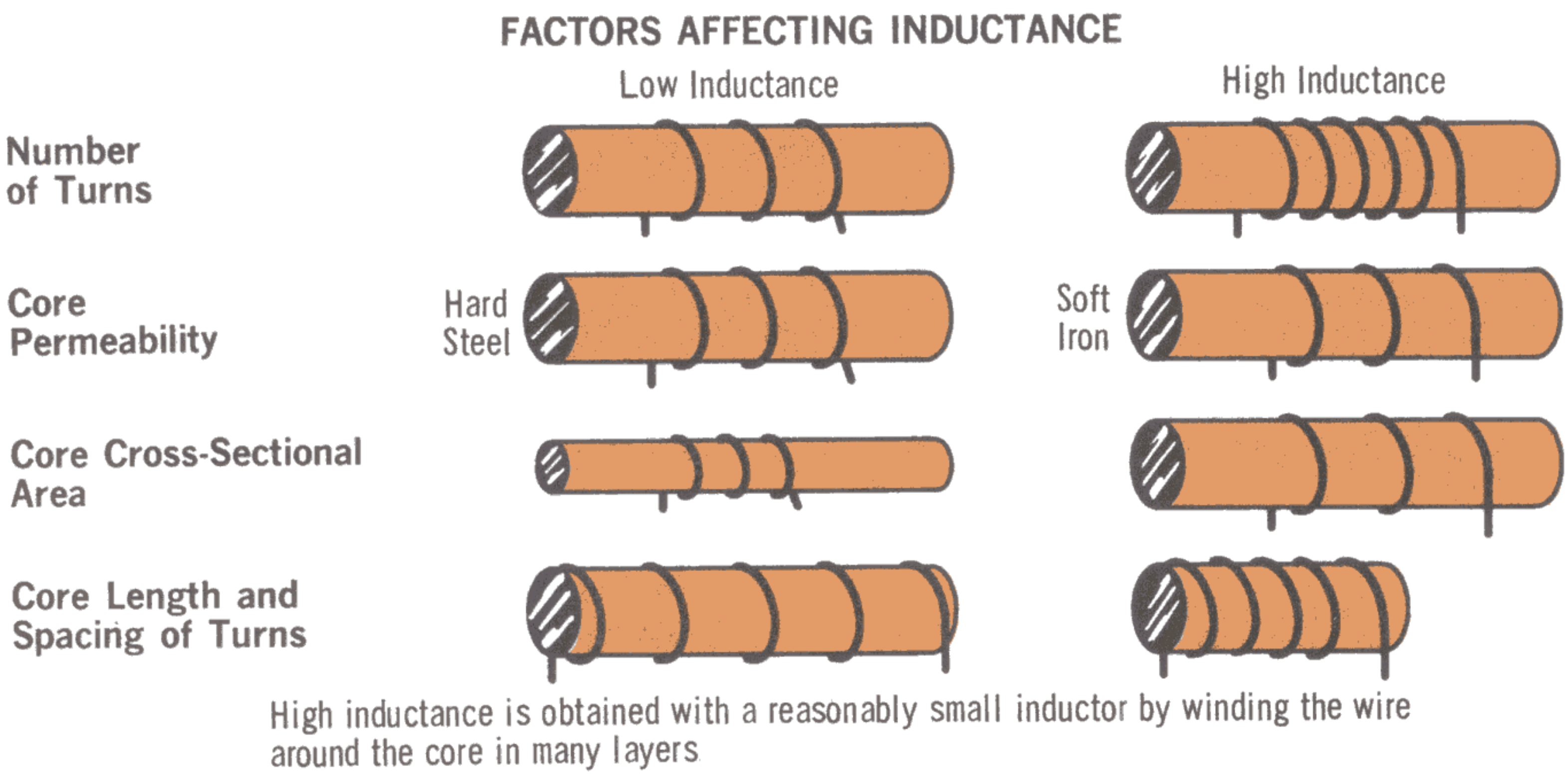




This is the symbol for an iron-core inductor

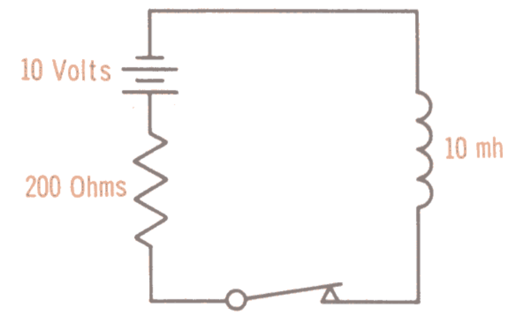
This is the symbol for an insulating-core inductor or an air-core inductor

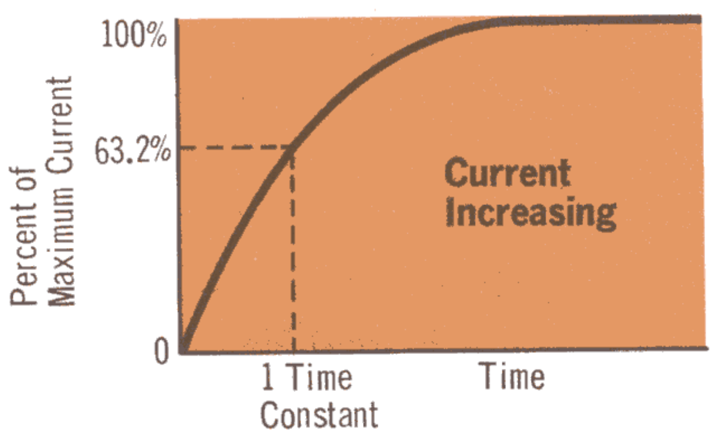
Factors Affecting Inductance



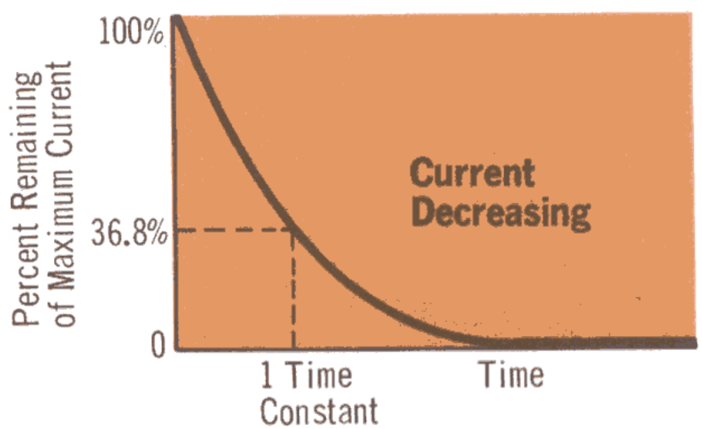
Inductor "Transient" Current

- DC applied to a series resistor and inductor circuit
- At t=0 inductor has a high "reactance" so no current
- After a while the inductor behaves like a short circuit
- The current rises "exponentially from 0 to V/R
- If the battery then drops top zero the reverse happens





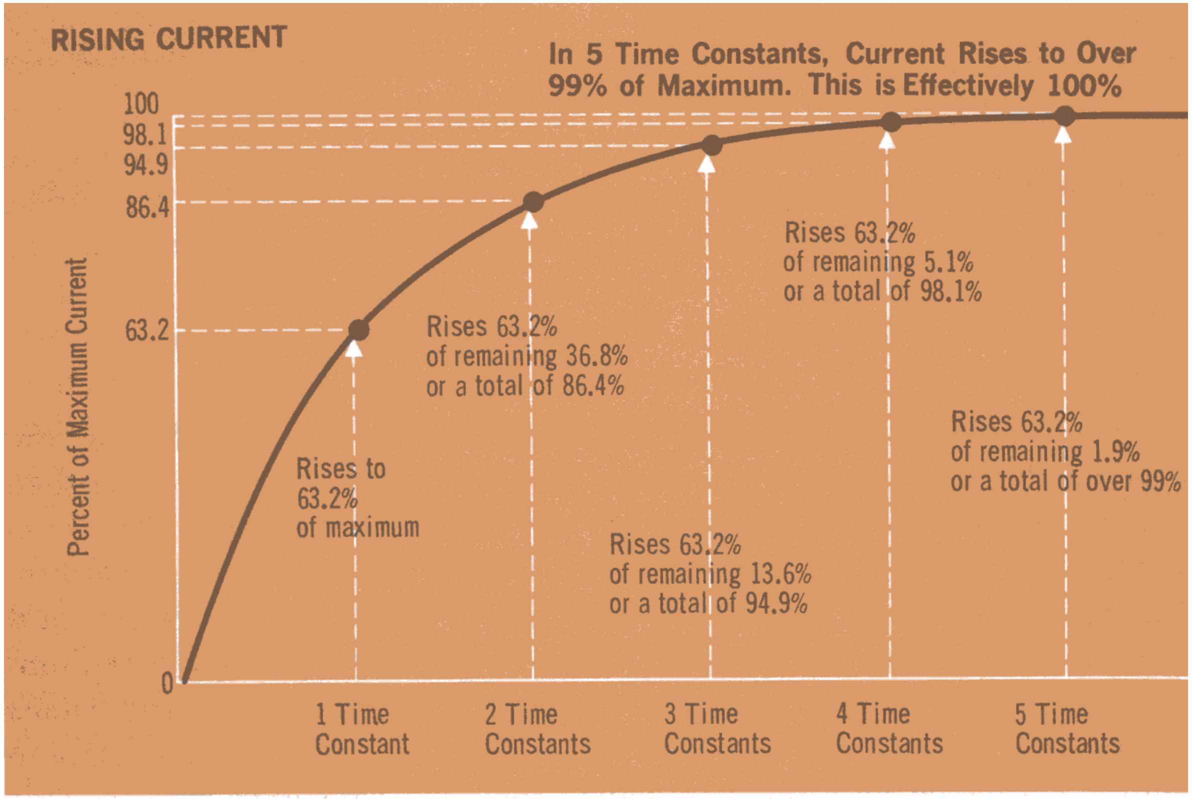
In 1 time constant the current increases from zero to 63.2% of its maximum value



In 1 time constant the current falls 63.2% from its maximum value, leaving 36.8%

Time Constant

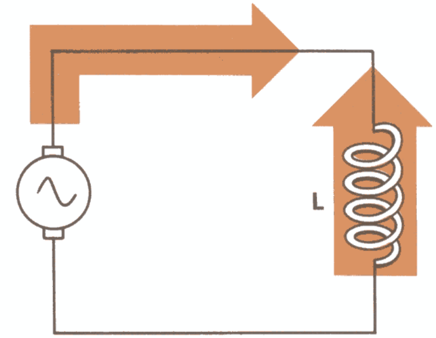
- Time constant
  $\tau = L/R$
- Formula
  $I = 1 - \varepsilon^{-(t/\tau)}$
  $\varepsilon = 2.7818$
  (base of the natural logarithm)

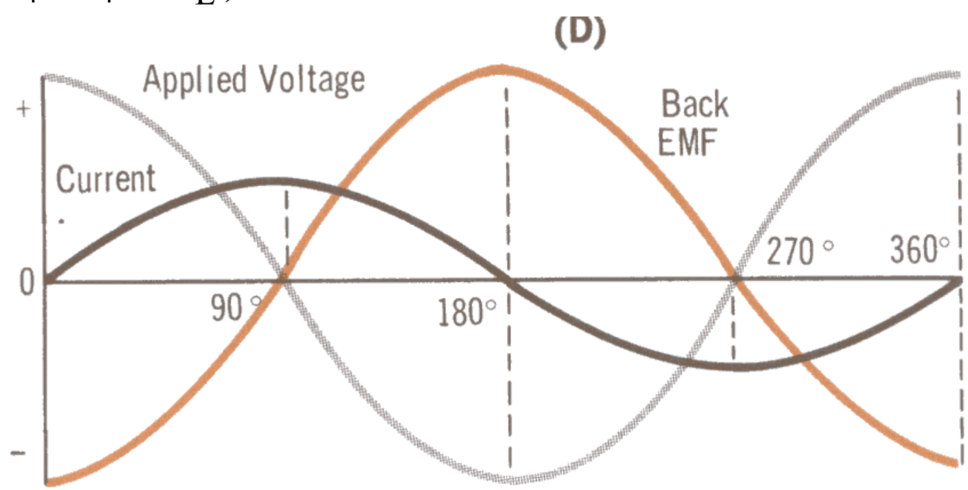


In each time constant, the current increases to a value 63.2% closer to its maximum value

AC Voltage and Current

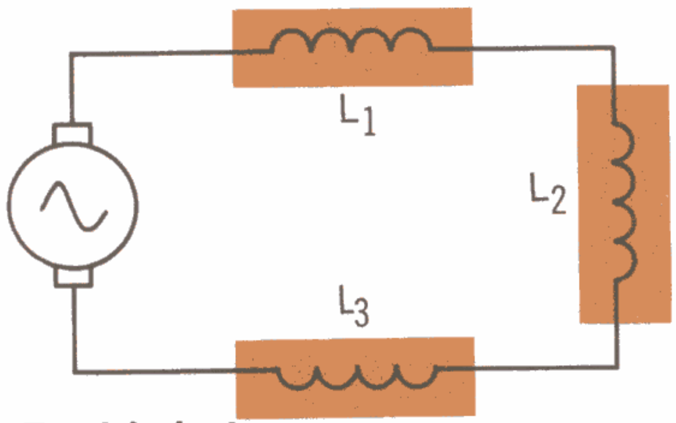
- Induced EMF "opposes" applied voltage
- Inductor current "lags" the voltage 90°
  (Eli the ice man)
- Inductor Reactance ($X_L = 2\pi f L$) determines the current magnitude ($|I| = |V| / X_L$)





In an inductance: (1) the applied voltage leads the current by 90°; (2) the back emf lags the current by 90°; and (3) the applied voltage and the back emf are 180° out of phase

Series and Parallel Inductors



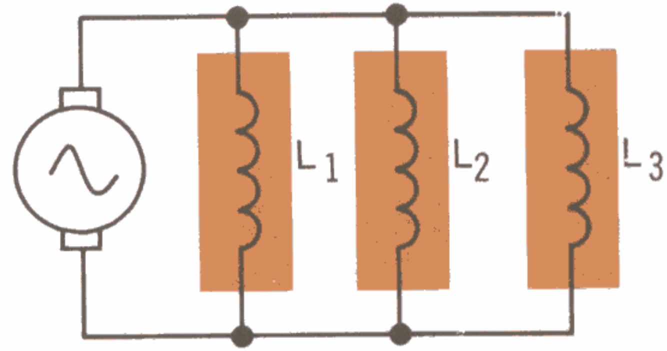
Total Inductance:

$L_{TOT} = L_1 + L_2 + L_3$

Total Inductive Reactance:

$X_{L\,TOT} = X_{L1} + X_{L2} + X_{L3}$

The total inductance or inductive reactance of series and parallel inductors is calculated the same as the total resistance of series and parallel resistance combinations



Total Inductance:

$$L_{TOT} = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}}$$

Total Inductive Reactance:

$$X_{L\,TOT} = \frac{1}{\frac{1}{X_{L1}} + \frac{1}{X_{L2}} + \frac{1}{X_{L3}}}$$

"Q"

- Quality factor "Q" of a coil is defined as the energy stored divided by the energy lost
  - Wire resistance
  - Losses in the "core"
- Calculating Q of an Inductor
  $Q = X_L / R_{eff}$

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