EEE 141
ELECTRICAL CIRCUITS

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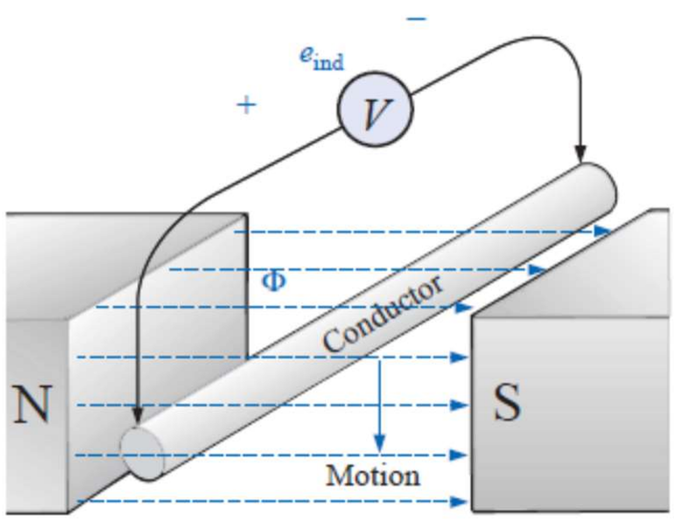
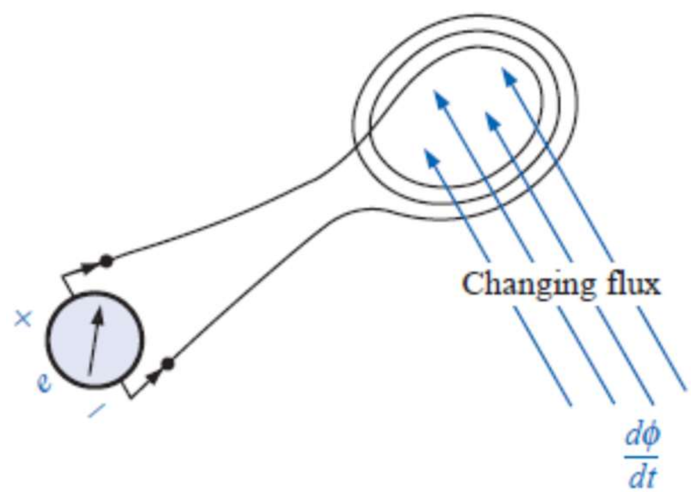
INDUCTORS

- Faraday’s law
- Inductors
- R-L Transients
- Series and parallel inductors

FARADAY'S LAW

- If a conductor is moved through a magnetic field so that it cuts magnetic lines of flux, a voltage will be induced across the conductor.
- If the conductor is held fixed and the magnetic field is moved so that its flux lines cut the conductor, the same effect will be produced.





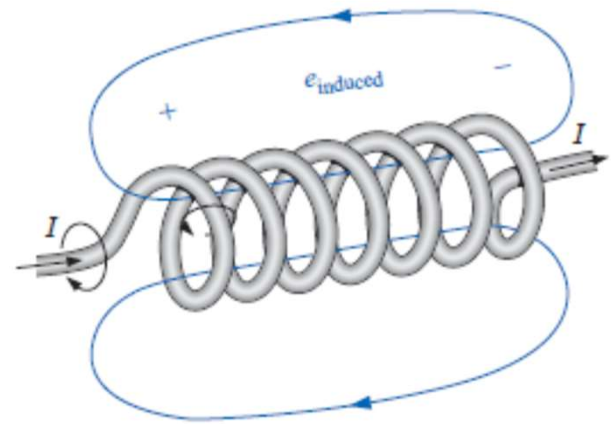
FARADAY'S LAW

- If a coil of N turns is placed in the region of a changing flux, a voltage will be induced across the coil as determined by Faraday's law:

$$\boxed{e = N\frac{d\phi}{dt}} \qquad \text{(volts, V)} \qquad \textbf{(12.1)}$$

where N represents the number of turns of the coil and $d\phi/dt$ is the instantaneous change in flux (in webers) linking the coil. The term *linking* refers to the flux within the turns of wire. The term *changing* simply indicates that either the strength of the field linking the coil changes in magnitude or the coil is moved through the field in such a way that the number of flux lines through the coil changes with time.

LENZ'S LAW



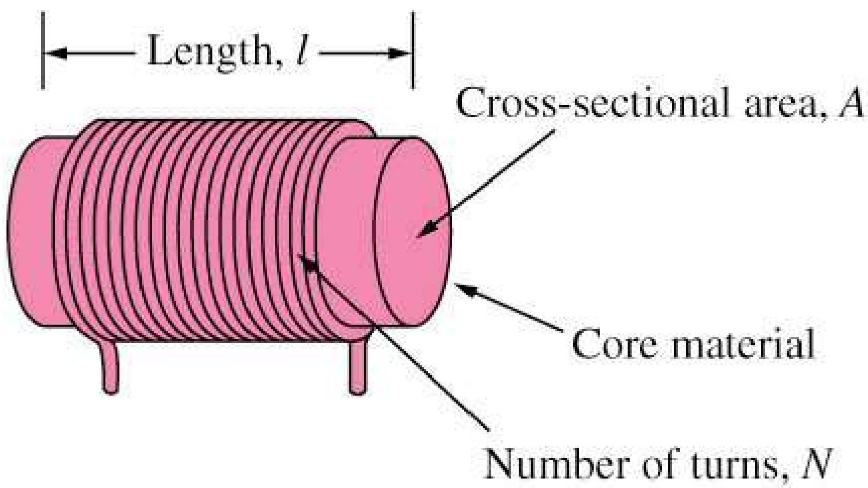
- The polarity of this induced voltage tends to establish a current in the coil that produces a flux that will oppose any change in the original flux.
- In other words, the induced effect (e_{ind}) is a result of the increasing current through the coil.
- However, the resulting induced voltage will tend to establish a current that will oppose the increasing change in current through the coil.
- An induced effect is always such as to oppose the cause that produced it.

INDUCTANCE

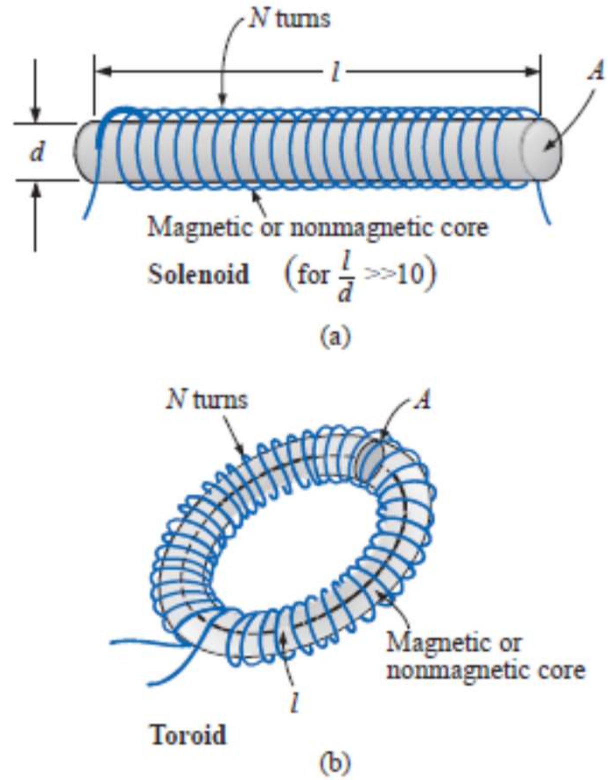
- The ability of a coil to oppose any change in current is a measure of the self-inductance L of the coil.
- Inductance is measured in henries (H).
- Inductors are coils of various dimensions designed to introduce specified amounts of inductance into a circuit.
- The inductance of a coil varies directly with the magnetic properties of the coil.
- Ferromagnetic materials, therefore, are frequently employed to increase the inductance by increasing the flux linking the coil.

INDUCTORS

An inductor is a passive element designed to store energy in its magnetic field.



$$L = \frac{N^2 \mu A}{l}$$



INDUCED VOLTAGE

The inductance of a coil is also a measure of the change in flux linking a coil due to a change in current through the coil.

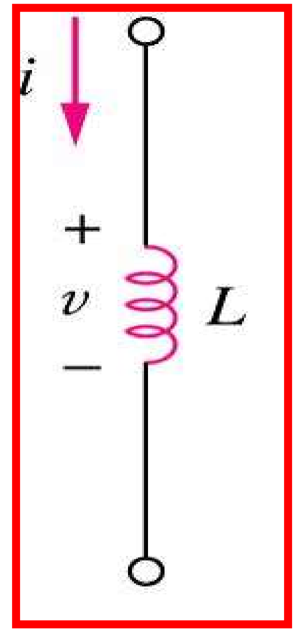
$$\boxed{L = N \frac{d\phi}{di}} \qquad \text{(H)}$$

$$v = L \frac{d\,i}{d\,t}$$

INDUCTORS

The current-voltage relationship of an inductor:

$$i = \frac{1}{L}\int_{t_0}^{t} v(t)\,dt + i(t_0)$$



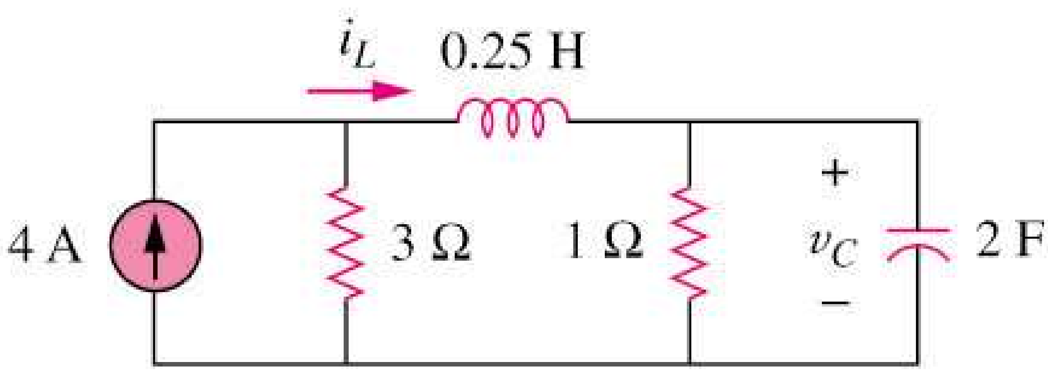
- The energy stored by an inductor:

$$w = \frac{1}{2} L\, i^2$$

- An inductor acts like a short circuit to dc (di/dt = 0) and its current cannot change abruptly.

INDUCTORS (EXAMPLE)

Determine v_c, i_L, and the energy stored in the capacitor and inductor in the circuit of circuit shown below under dc conditions.



Answer:

$i_L = 3A$

$v_C = 3V$

$w_L = 1.125J$

$w_C = 9J$

R-L TRANSIENTS

- At the instant the switch is closed, the inductance of the coil will prevent an instantaneous change in current through the coil.
- The potential drop across the coil, v_L, will equal the impressed voltage E as determined by Kirchhoff's voltage law since $v_R = iR = 0$ V.

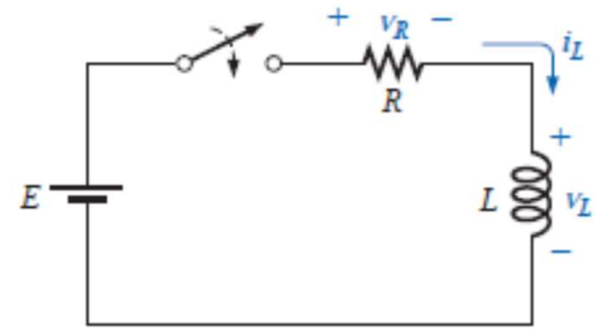


FIG. 12.14
Basic R-L transient network.

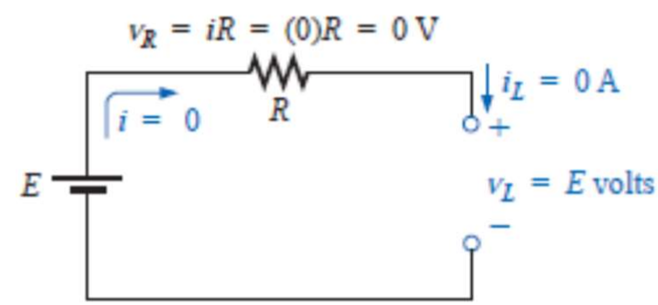
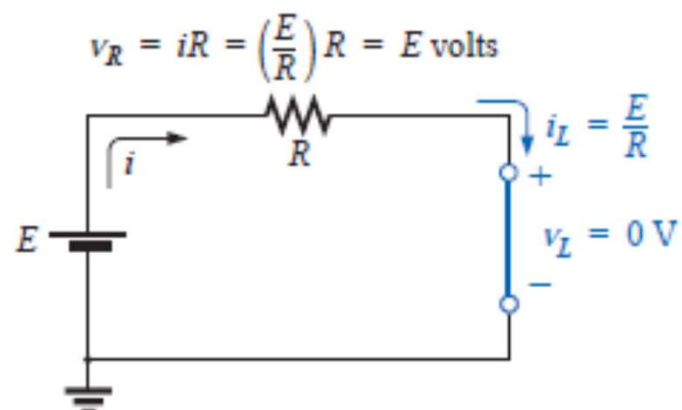


FIG. 12.15
Circuit of Fig. 12.14 the instant the switch is closed.

R-L TRANSIENTS

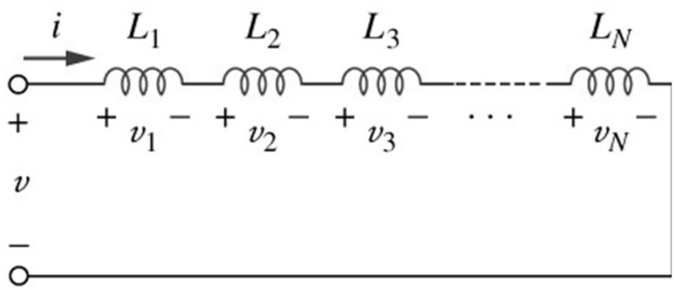
- The current will continue to increase until the voltage across the inductor drops to zero volts and the full impressed voltage appears across the resistor.
- An ideal inductor assumes a short-circuit equivalent in a dc network once steady-state conditions have been established.

$$i_L = I_m(1 - e^{-t/\tau}) = \frac{E}{R}(1 - e^{-t/(L/R)})$$



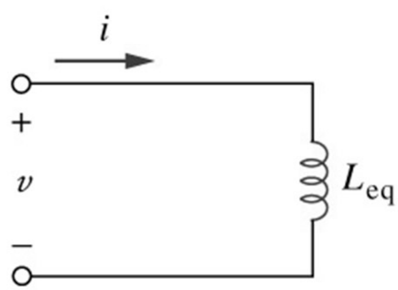
SERIES AND PARALLEL INDUCTORS

The equivalent inductance of **series-connected** inductors is the sum of the individual inductances.



(a)

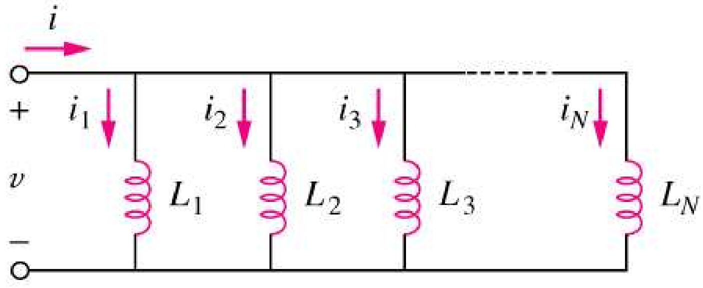
$$L_{eq} = L_1 + L_2 + ... + L_N$$



(b)

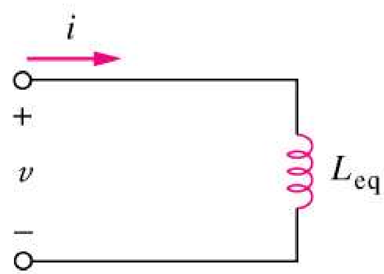
SERIES AND PARALLEL INDUCTORS

The equivalent capacitance of **parallel** inductors is the reciprocal of the sum of the reciprocals of the individual inductances.



(a)

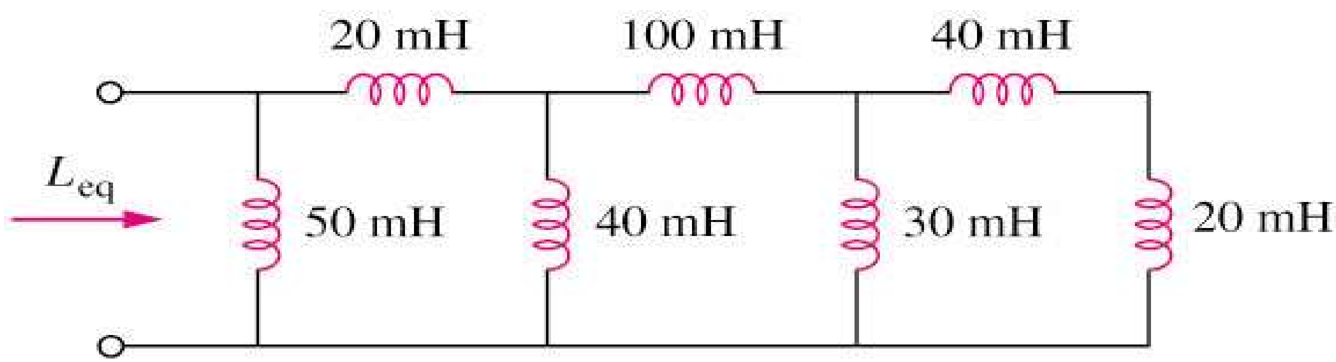
$$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots + \frac{1}{L_N}$$



(b)

SERIES AND PARALLEL INDUCTORS (EXAMPLE)

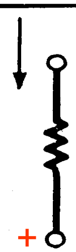
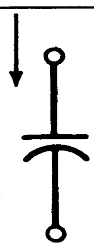
Calculate the equivalent inductance for the inductive ladder network in the circuit shown below:



Answer:

L_{eq} = <u>25mH</u>

CURRENT AND VOLTAGE RELATIONSHIP FOR R, L, C

Circuit element	Units	Voltage	Current	Power
 **Resistance**	ohms (Ω)	$v = Ri$ (Ohm's law)	$i = \frac{v}{R}$	$p = vi = i^2R$
 **Inductance**	henries (H)	$v = L\frac{di}{dt}$	$i = \frac{1}{L}\int v\,dt + k_1$	$p = vi = Li\frac{di}{dt}$
 **Capacitance**	farads (F)	$v = \frac{1}{C}\int i\,dt + k_2$	$i = C\frac{dv}{dt}$	$p = vi = Cv\frac{dv}{dt}$