



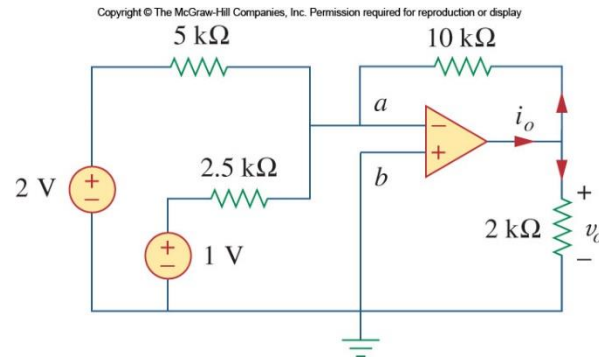
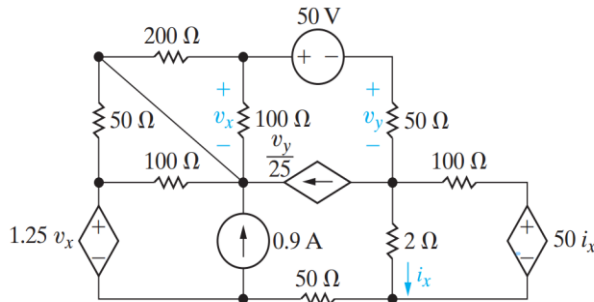
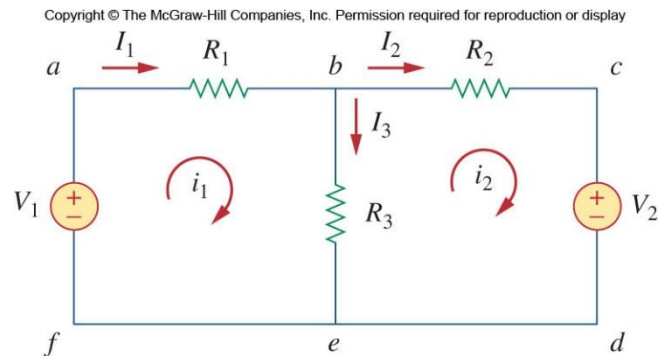
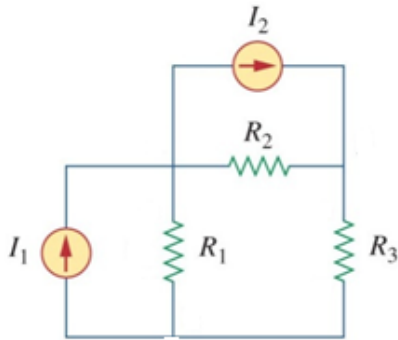
# Lecture 5

## - RC/RL First-Order Circuits

Beginning of **Temporal** Behavior Analysis  
of Circuits



- Till now we discussed static analysis of a circuit
  - Responses at a given time depend only on inputs at that time.
  - Circuit responds to input changes infinitely fast.



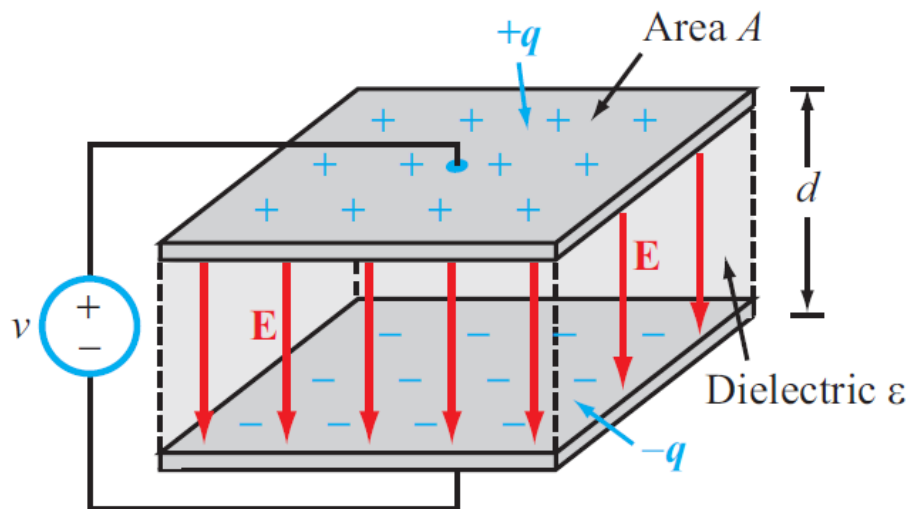


# Outline

- Capacitors and inductors
- Natural response of RC/RL circuits
- Step response of RC/RL circuits
- Others

# Capacitors

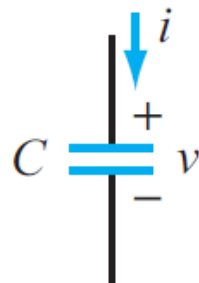
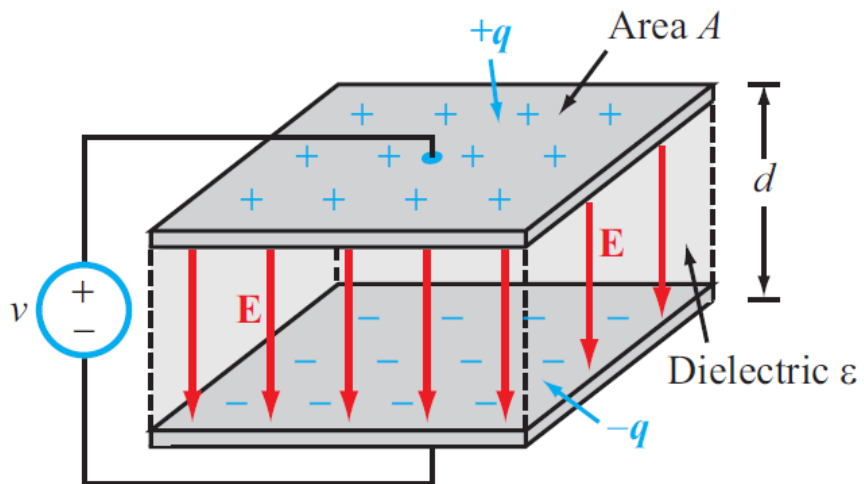
Storage element that stores energy in electric field



Parallel plate capacitor

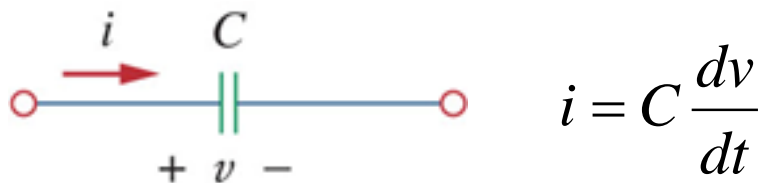


# V-I Relationship of Capacitors





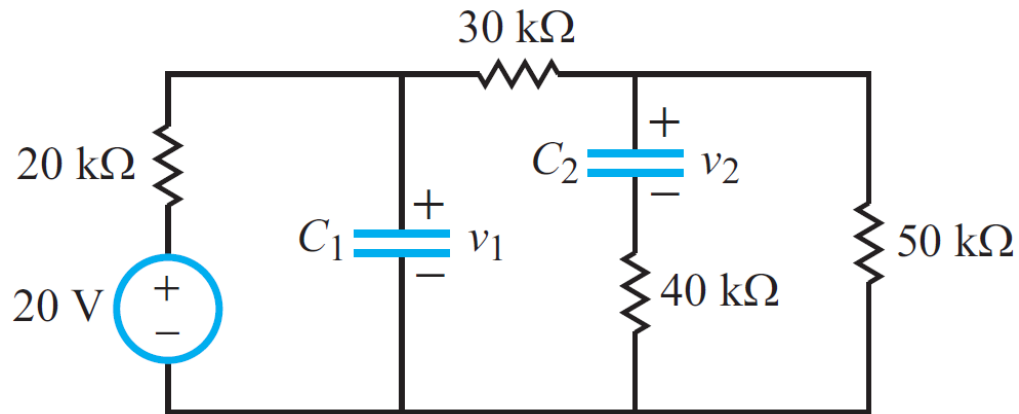
# Stored Energy



- The instantaneous power delivered to the capacitor is
- The energy stored in a capacitor is:

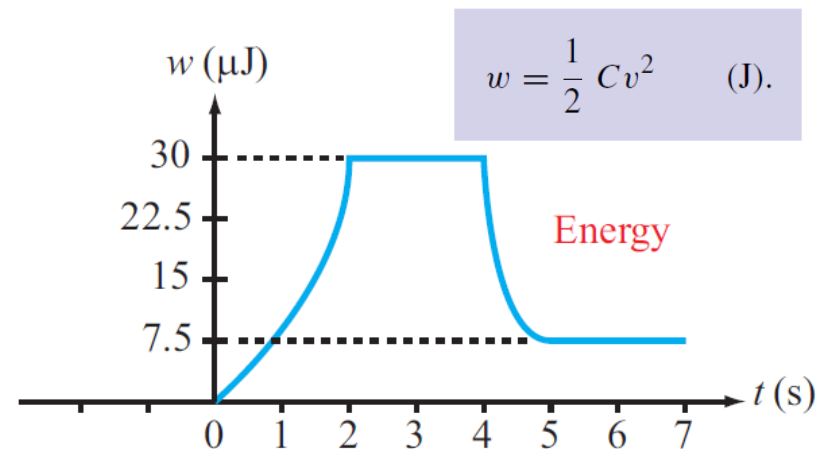
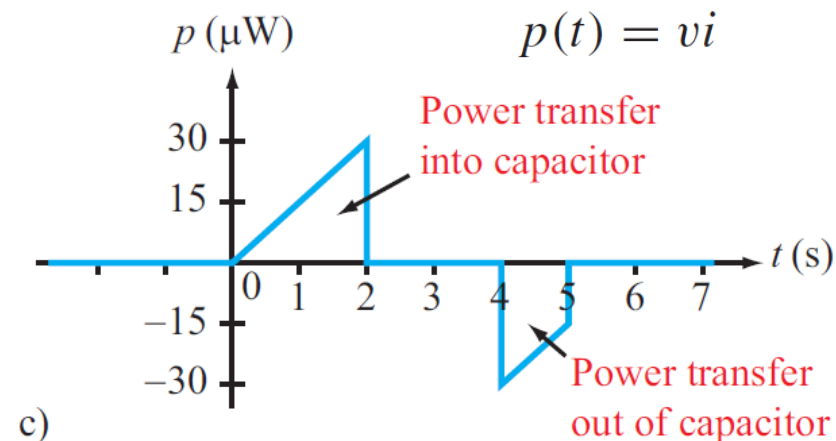
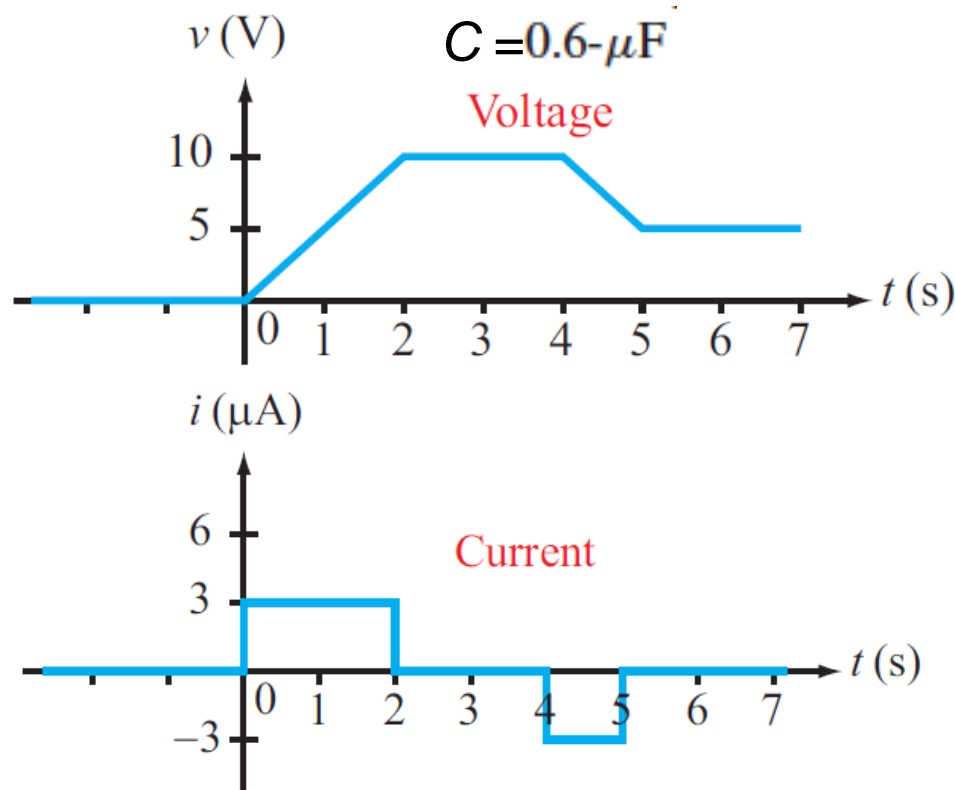
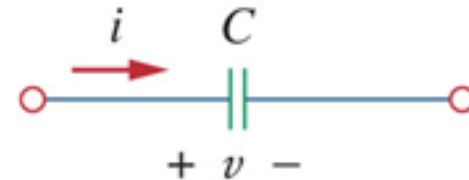


## Example-1



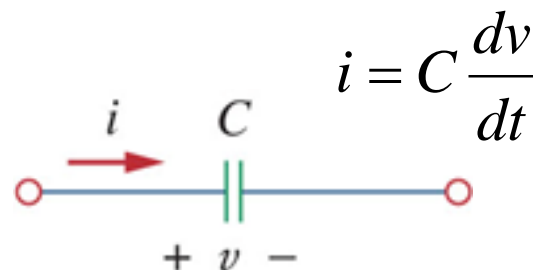
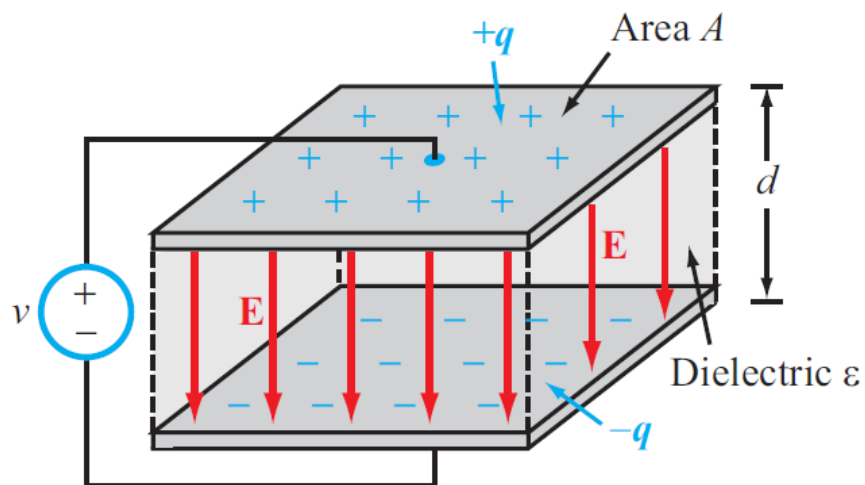


## Example-2 Capacitor Response



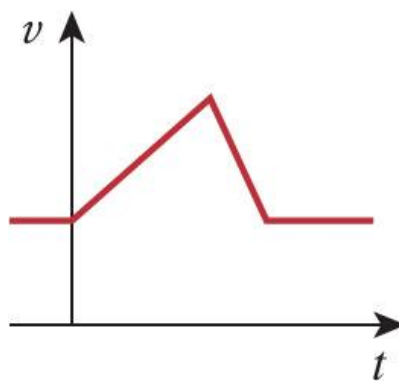


# Important Property of Capacitors

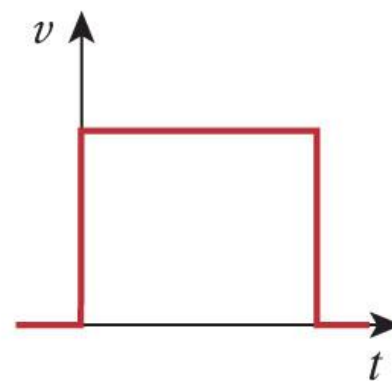


$$i = C \frac{dv}{dt}$$

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(a)

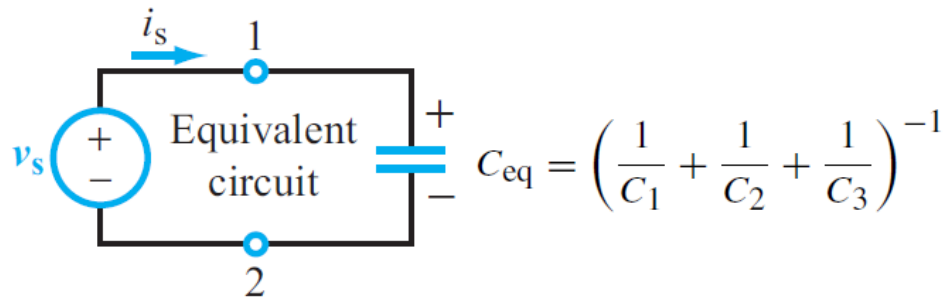
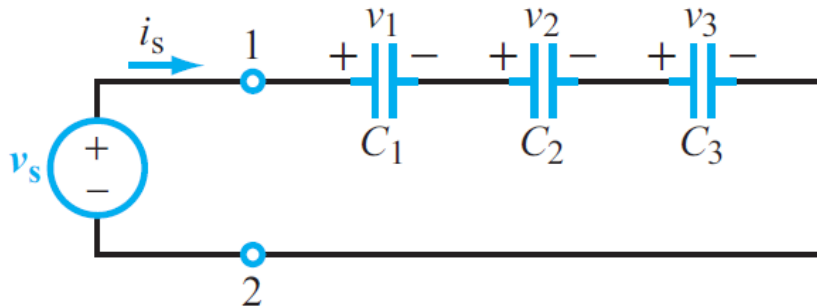


(b)



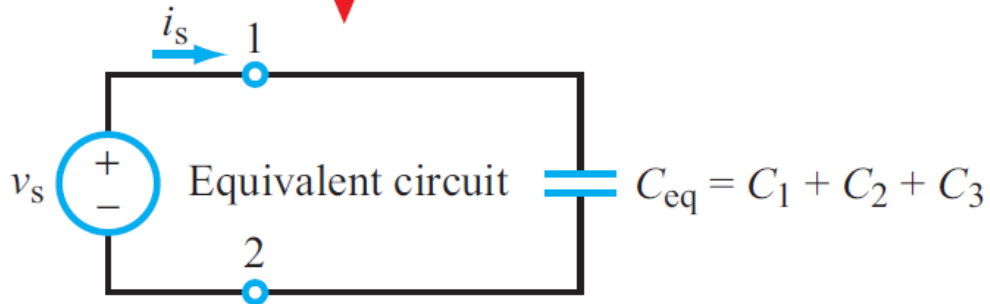
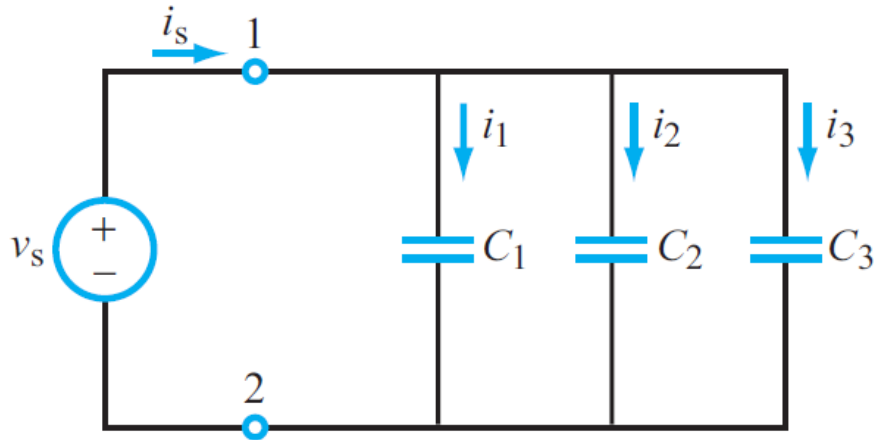
# Capacitors in Series

## Combining In-Series Capacitors



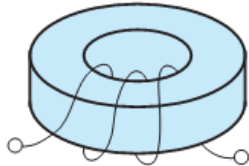


# Capacitors in Parallel

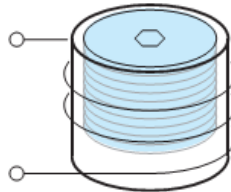


# Inductors

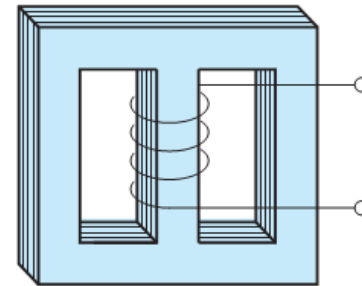
- A storage element that stores energy in magnetic field.
  - They have applications in power supplies, transformers, radios, TVs, radars, and electric motors.
- Any conductor has inductance, but the effect is typically enhanced by coiling the wire up.



(a) Toroidal inductor

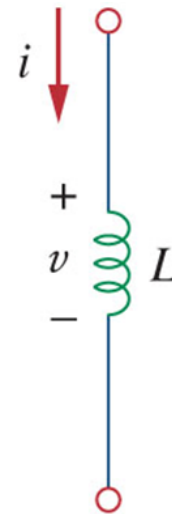
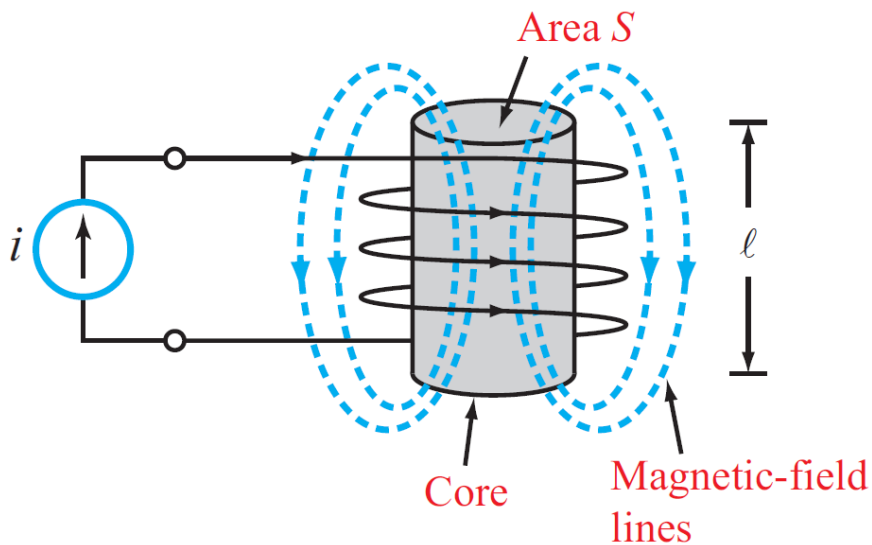


(b) Coil with an iron-oxide slug that can be screwed in or out to adjust the inductance



(c) Inductor with a laminated iron core

# V-I Relationship of Inductors

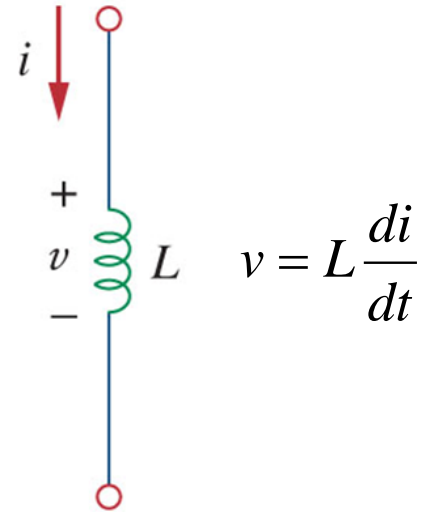


$$v = L \frac{di}{dt}$$



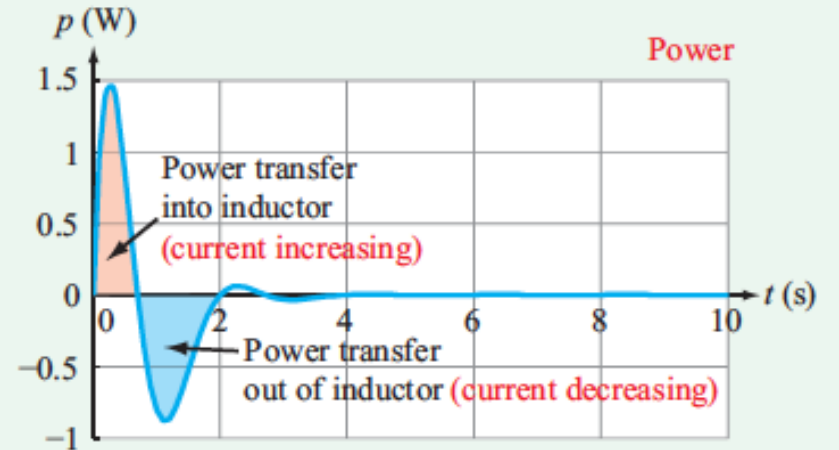
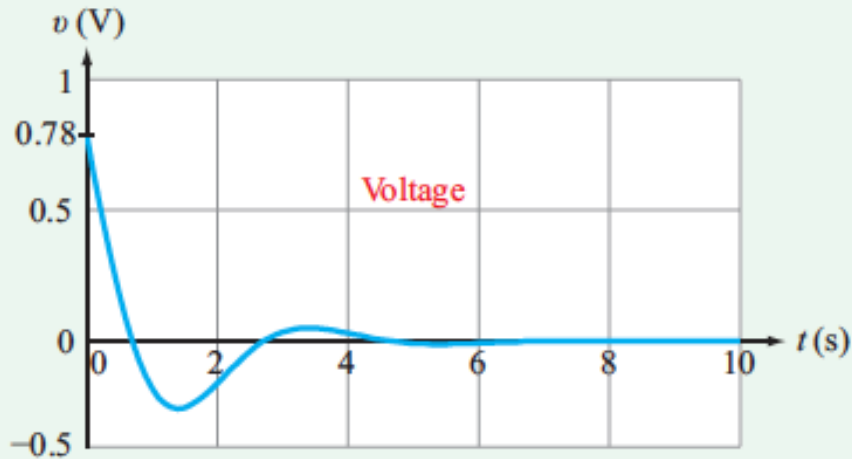
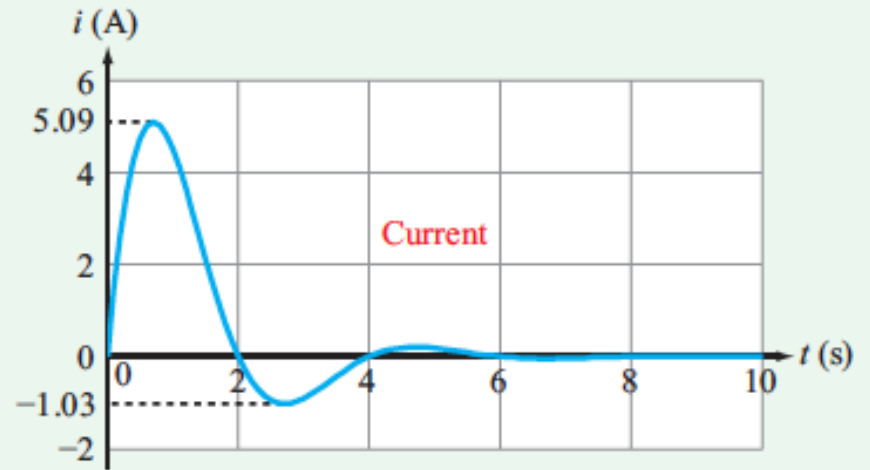
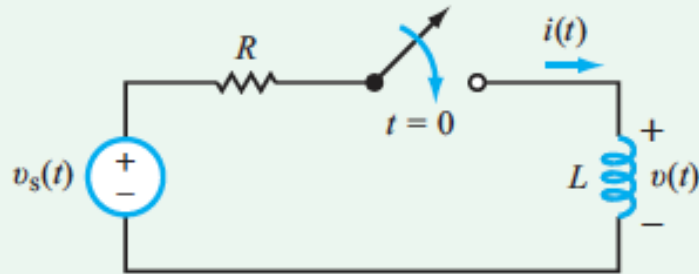
# Energy Stored in an Inductor

- The power delivered to the inductor is:
- The energy stored is:



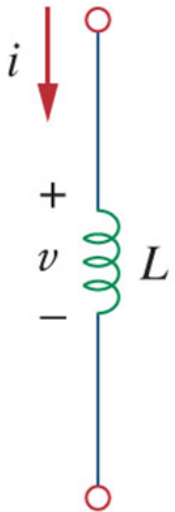


# Inductor Response



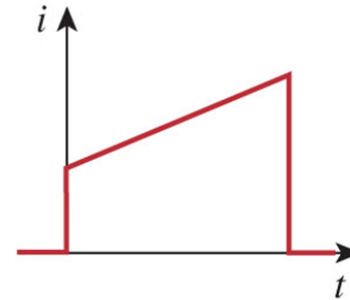
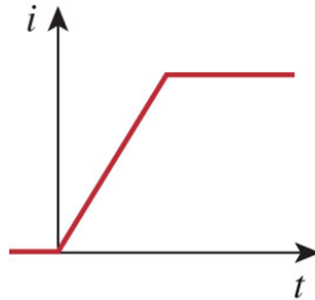


# Important Property of Inductors



$$v = L \frac{di}{dt}$$

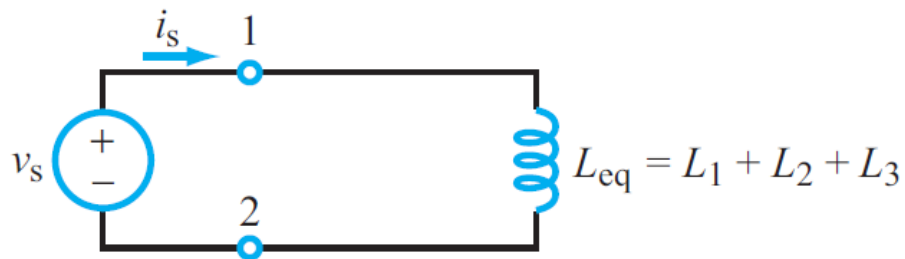
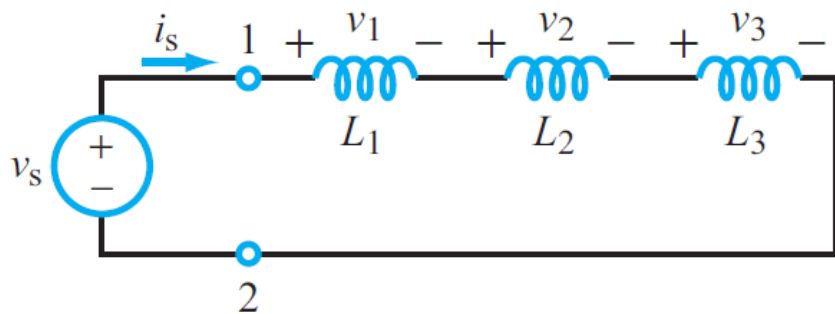
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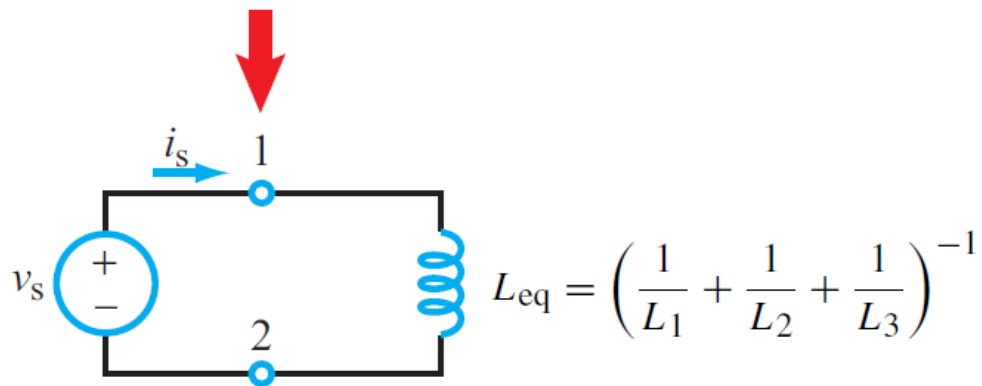
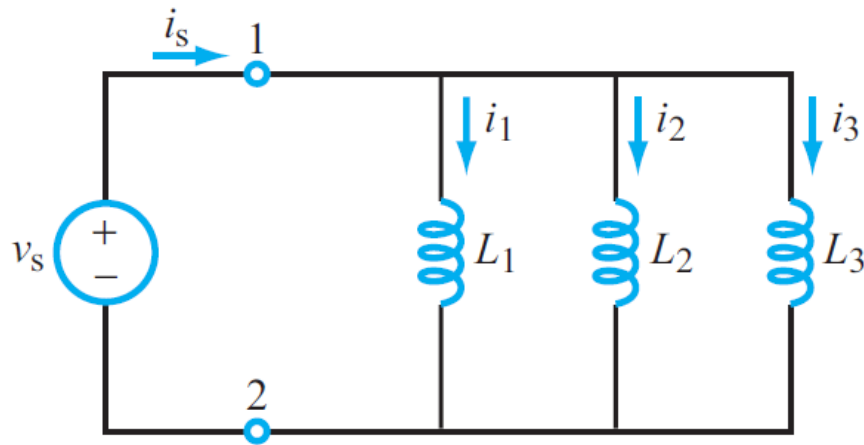
# Inductors in Series





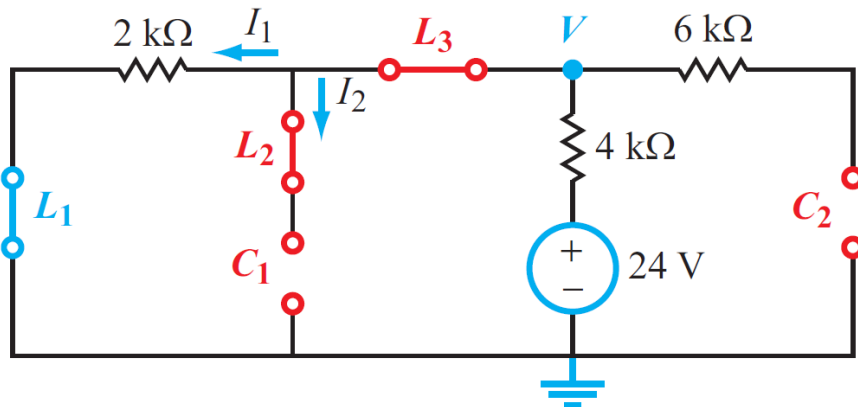
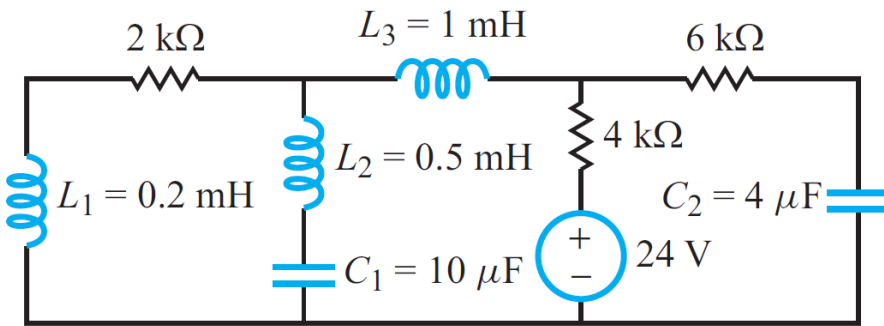
# Inductors in Parallel

## Combining In-Parallel Inductors





## Example





# Summary of Resistors, Capacitors and Inductors

**Table 5-4:** Basic properties of  $R$ ,  $L$ , and  $C$ .

Property	$R$	$L$	$C$
$i$ - $v$ relation	$i = \frac{v}{R}$	$i = \frac{1}{L} \int_{t_0}^t v dt' + i(t_0)$	$i = C \frac{dv}{dt}$
$v$ - $i$ relation	$v = iR$	$v = L \frac{di}{dt}$	$v = \frac{1}{C} \int_{t_0}^t i dt' + v(t_0)$
$p$ (power transfer in)	$p = i^2 R$	$p = Li \frac{di}{dt}$	$p = Cv \frac{dv}{dt}$
$w$ (stored energy)	0	$w = \frac{1}{2} Li^2$	$w = \frac{1}{2} Cv^2$
Series combination	$R_{eq} = R_1 + R_2$	$L_{eq} = L_1 + L_2$	$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$
Parallel combination	$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$	$\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}$	$C_{eq} = C_1 + C_2$
dc behavior	no change	short circuit	open circuit
Can $v$ change instantaneously?	yes	yes	no
Can $i$ change instantaneously?	yes	no	yes