Exam #4 → ~~Thursday, March 21~~

→ Tuesday, March 26

→ Thursday, March 28

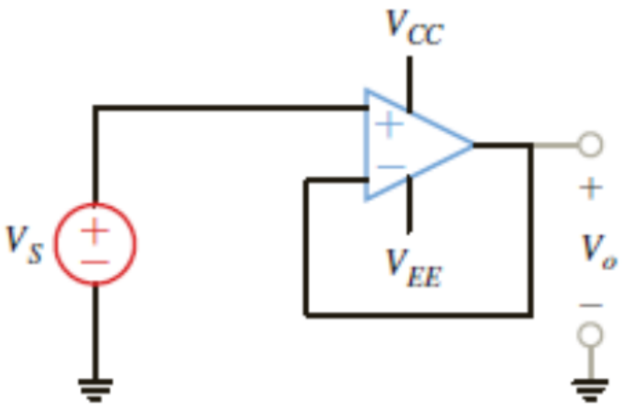
Concepts Chapter #4 & #6:

1) Op-Amp
   - Model
   - Circuit Analysis
     - Ideal behavior
     - Non-ideal behavior
2) Capacitor / Inductor
   - Model / Behavior
   - DC Analysis
   - Series / Parallel Combination

***** "Bate": bring your own set of equations (no problems, photocopies, solutions, etc)… subject to approval by the professor**

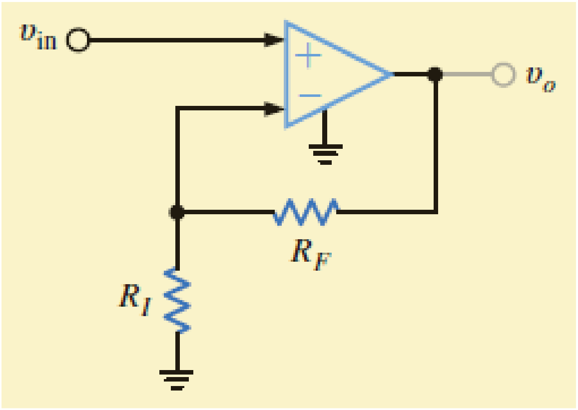
Last Lecture → Op-Amp Amplifiers

- **Unity – Gain Amp.**



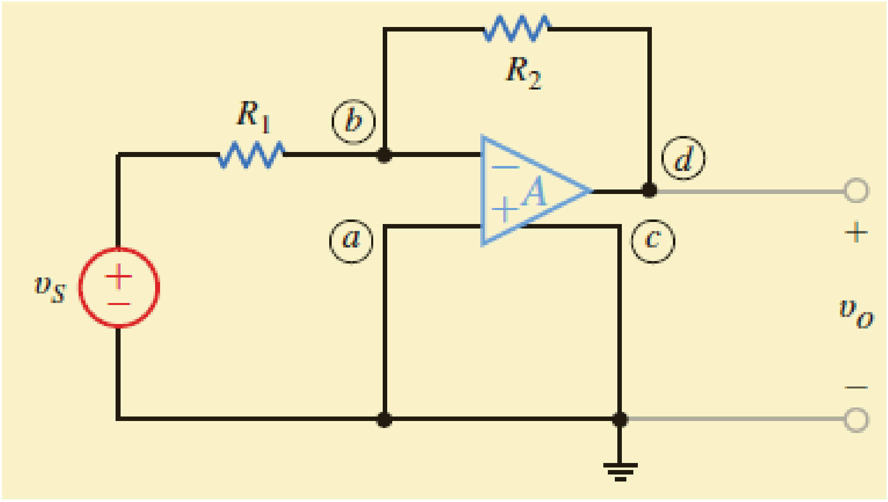
$$\frac{V_0}{V_s} \approx 1$$

- **Non-Inverting Amp.**



$$\frac{V_0}{V_s} \approx 1 + \frac{R_F}{R_I}$$

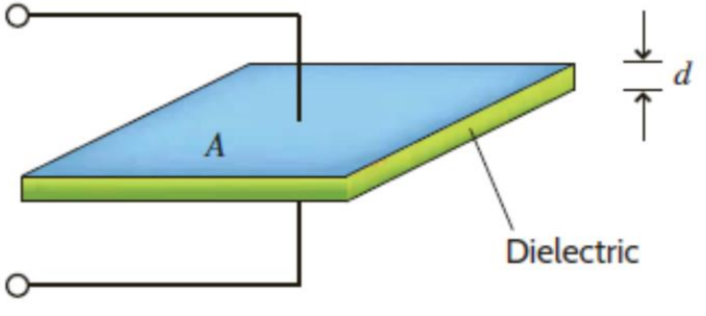
- **Inverting Amp**



$$\frac{V_0}{V_s} \approx -\frac{R_2}{R_1}$$

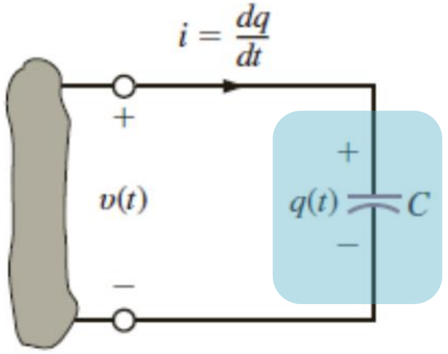
Last Lecture → Capacitor

… a circuit element that consists of two conducting surfaces separated by dielectric material



(a)

Simplified Capacitor



(b)

Symbol

Typical Capacitors

Capacitance (C) → $C = \frac{\varepsilon_0 A}{d}$ ← permittivity of free space

Unit → farads (F) = coulombs per volts

$$q = C \cdot v \qquad i = C \cdot \frac{dv}{dt}$$

$$v(t) = v(t_0) + \frac{1}{C} \cdot \int_{t_0}^{t} i(x)dx$$

$$p(t) = C \cdot v(t)\frac{dv(t)}{dt}$$

$$w_c(t) = \frac{1}{2} C \cdot v(t)^2$$

Example 6.1

If the charge accumulated on two parallel conductors charge to 12V is 600 pC, what is the capacitance of the parallel conductors?

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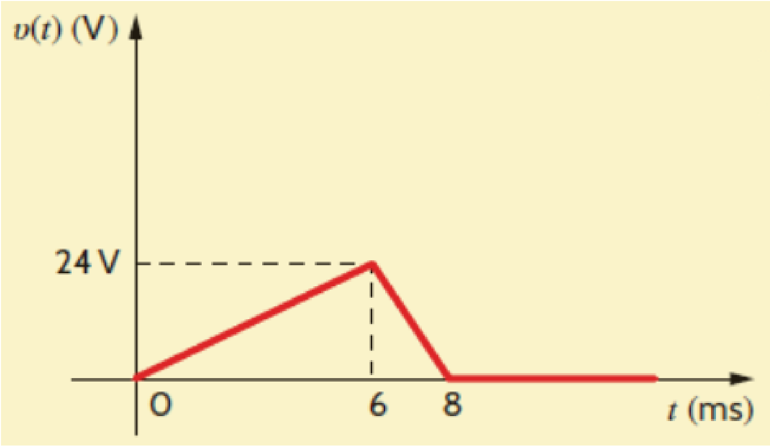
$$v = 12V \qquad q = 600\,pC$$

$$C = \frac{q}{v} = \frac{600p}{12} = 50pF$$

Example 6.2

If voltage across a 5-µF capacitor has the waveform shown below, determine the current waveform?



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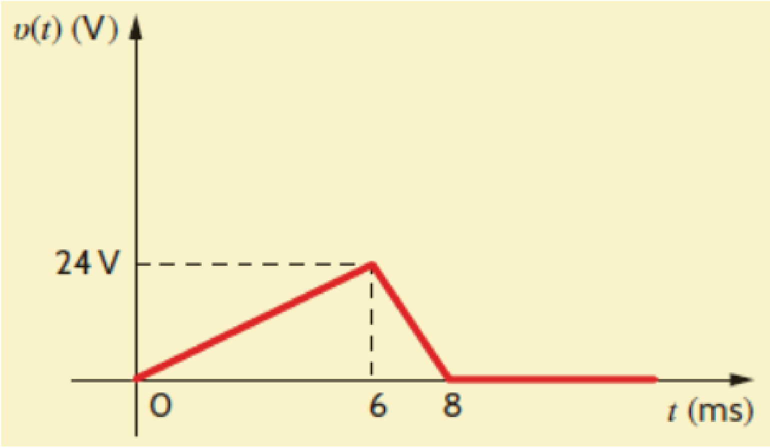
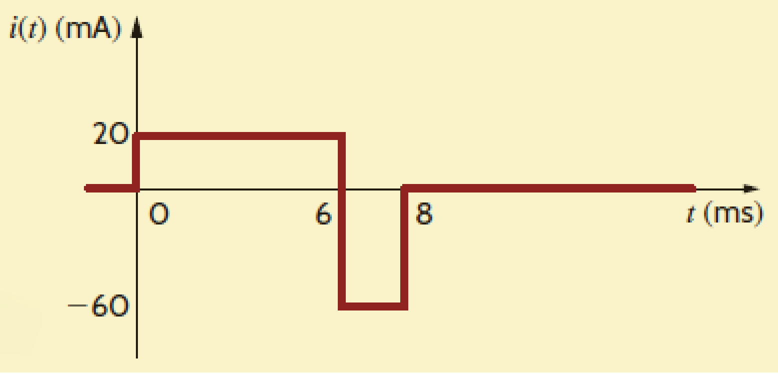


$$i = C \cdot \frac{dv}{dt} = ?$$



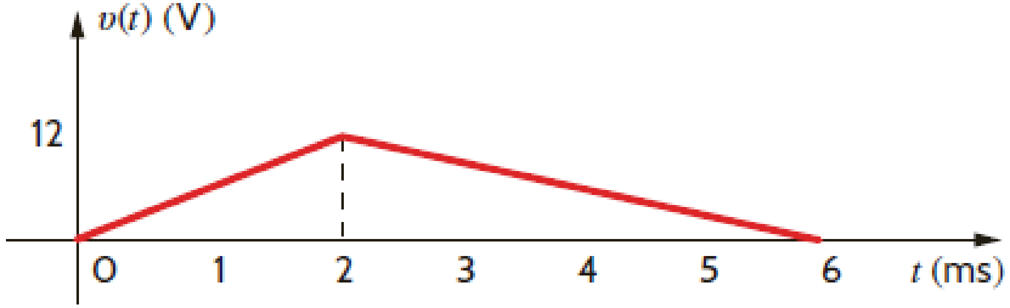
$$v(t) = 4k \cdot t \quad \rightarrow t = [0:6]$$

$$24 - 12k \cdot (t - 6m) \quad \rightarrow t = [6:8]$$

$$0 \quad \rightarrow t = [8:\infty]$$

Learning Assessment E6.2-E6.3

The voltage across a 2-uF capacitor is provided below. Determine the waveforms for the current, power, and energy and compute the energy stored in the electric field of the capacitor at t=2ms.



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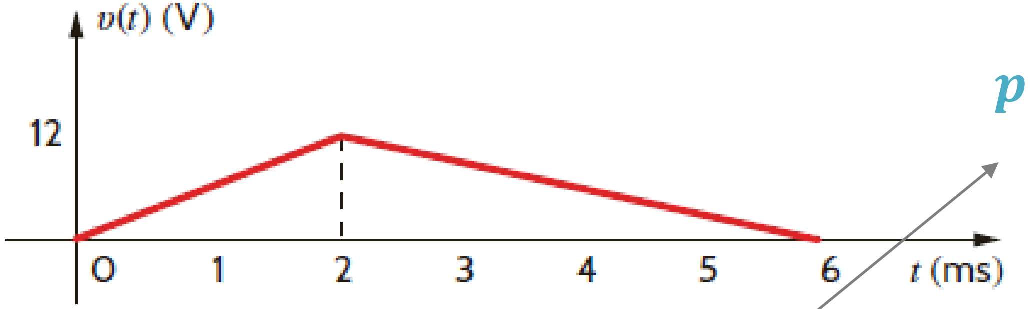


$$p(t) = C \cdot v(t)\frac{dv(t)}{dt} =$$

$$v(t) =$$

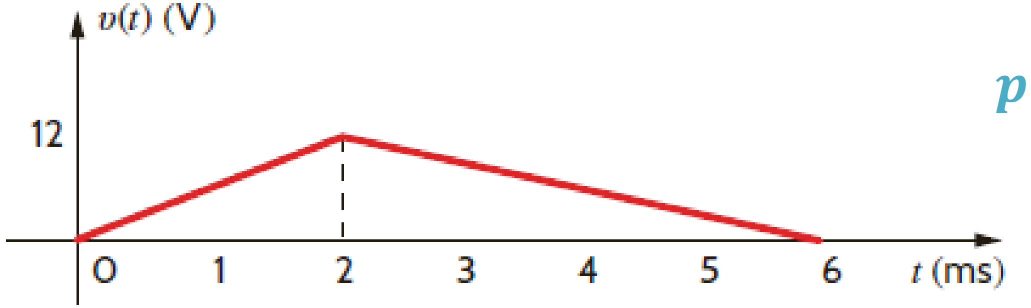
$$w_c(t) = \frac{1}{2}C \cdot v(t)^2 =$$

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

$$w_c(t = 2m) =$$

Learning Assessment E6.2-E6.3

The voltage across a 2-uF capacitor is provided below. Determine the waveforms for the current, power, and energy and compute the energy stored in the electric field of the capacitor at t=2ms.



$$p(t) = C \cdot v(t)\frac{dv(t)}{dt} = \begin{cases} 72 \cdot t\ W & \rightarrow t = [0:2] \\ -72 + 18 \cdot (t - 2m)\ W & \rightarrow t = [2:6] \end{cases}$$

$$v(t) = \begin{cases} 6k \cdot t & \rightarrow t = [0:2] \\ 12 - 3k \cdot (t - 2m) & \rightarrow t = [2:6] \end{cases}$$

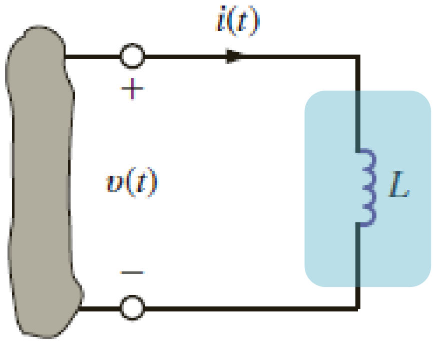
$$w_c(t) = \frac{1}{2} C \cdot v(t)^2 = \begin{cases} 36 \cdot t^2\ J & \rightarrow t = [0:2] \\ [17 - 3k \cdot t]^2\ uJ & \rightarrow t = [2:6] \end{cases}$$

$$i = C \cdot \frac{dv}{dt} = \begin{cases} 12\ mA & \rightarrow t = [0:2] \\ -6\ mA & \rightarrow t = [2:6] \end{cases}$$

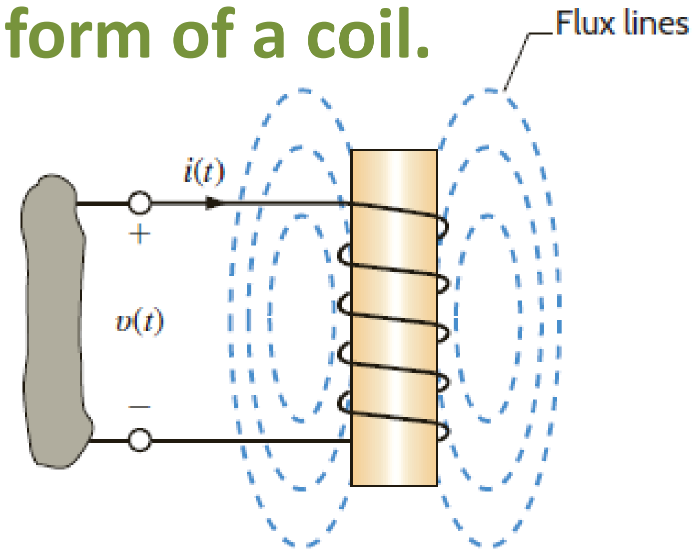
$$w_c(t = 2m) = 144\ uJ$$

Inductor

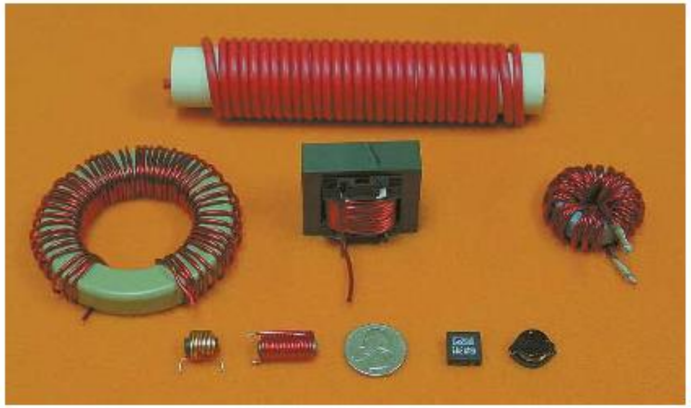
… a circuit element that consists of a conducting wire usually in the form of a coil.



Symbol



Simplified Inductor



Typical Inductors

Inductance (L)

↓

Unit → Henry (H) = 1 volt-second per ampere

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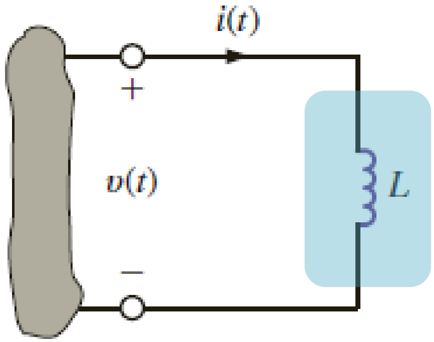
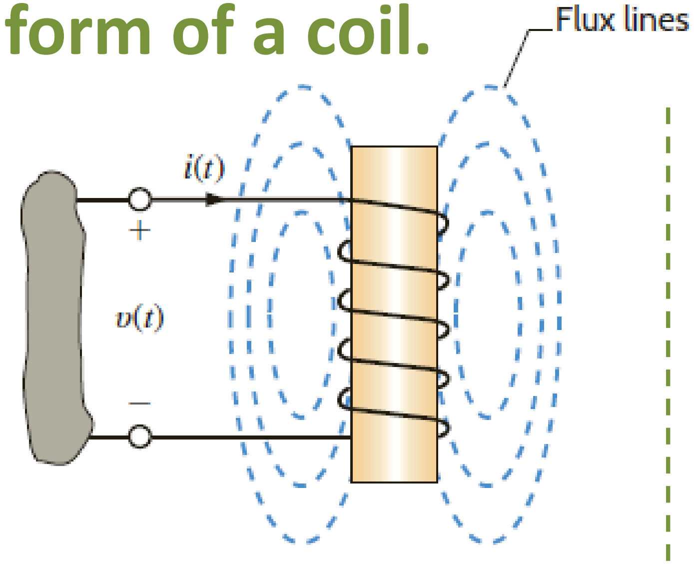
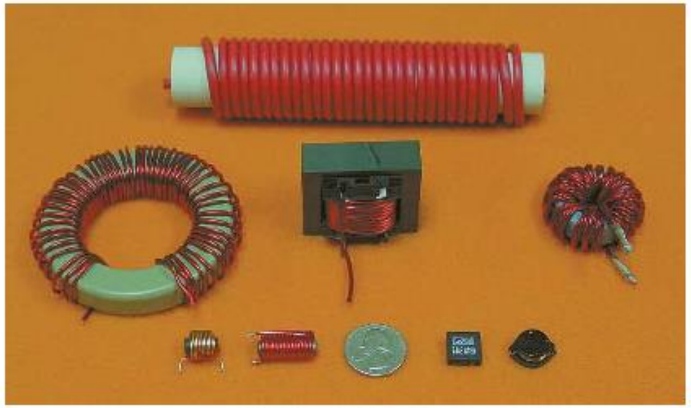


Symbol



Simplified Inductor

Typical Inductors



Inductance (L)

Unit → Henry (H) = 1 volt-second per ampere

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

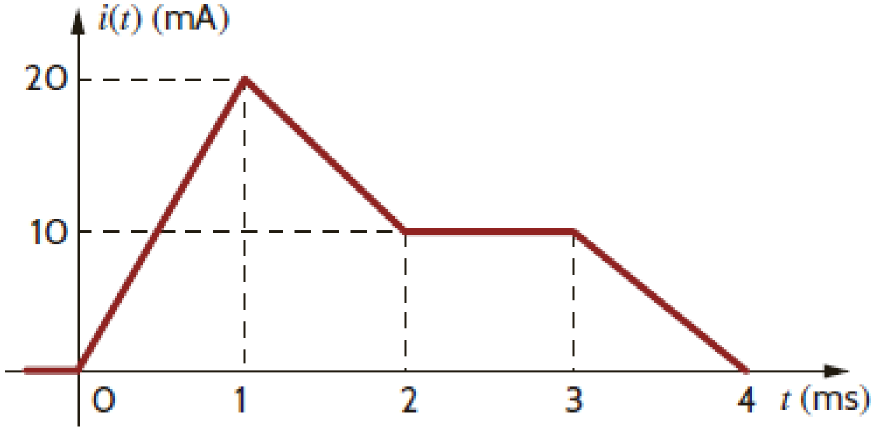
$$i(t) = i(t_0) + \frac{1}{L} \cdot \int_{t_0}^{t} v(x)dx$$

$$p(t) = L \cdot i(t)\frac{di(t)}{dt}$$

$$w_L(t) = \frac{1}{2} L \cdot i(t)^2$$

Learning Assessment E6.6-E6.7

The current across a 5-mH inductor is provided below. Determine the waveforms for the voltage, power, and energy and compute the energy stored in the magnetic field of the inductor at t=1.5ms.



Learning Assessment E6.6-E6.7

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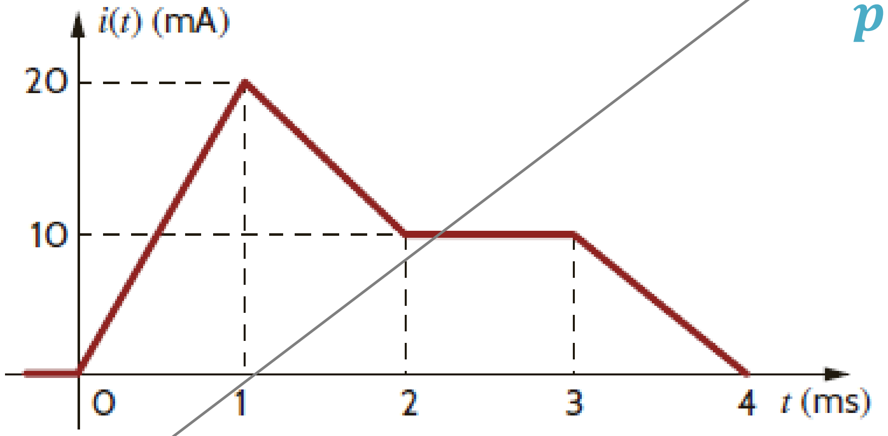

$$i(t) =$$

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

$$p(t) = L \cdot i(t)\frac{di(t)}{dt} =$$

$$w_L(t) = \frac{1}{2}L \cdot i(t)^2 =$$

$$w_L(t = 1.5m) =$$

Learning Assessment E6.6-E6.7

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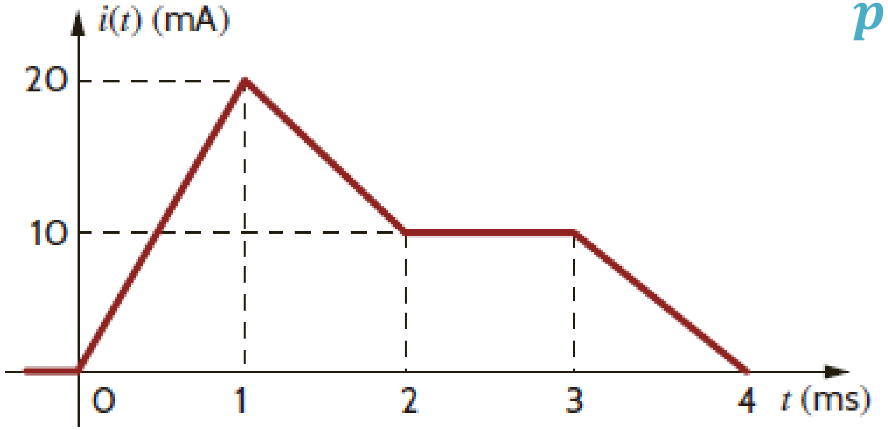


$$i(t) = \begin{cases} 20 \cdot t \ A & \rightarrow t = [0:1] \\ 20m - 10 \cdot (t - 1m) \ A & \rightarrow t = [1:2] \\ 10 \ mA & \rightarrow t = [2:3] \\ 10m - 10 \cdot (t - 3m) \ A & \rightarrow t = [3:4] \end{cases}$$

$$v = L \cdot \frac{di}{dt} = \begin{cases} 100 \ mV & \rightarrow t = [0:1] \\ -50 \ mV & \rightarrow t = [1:2] \\ 0 & \rightarrow t = [2:3] \\ -50 \ mV & \rightarrow t = [3:4] \end{cases}$$

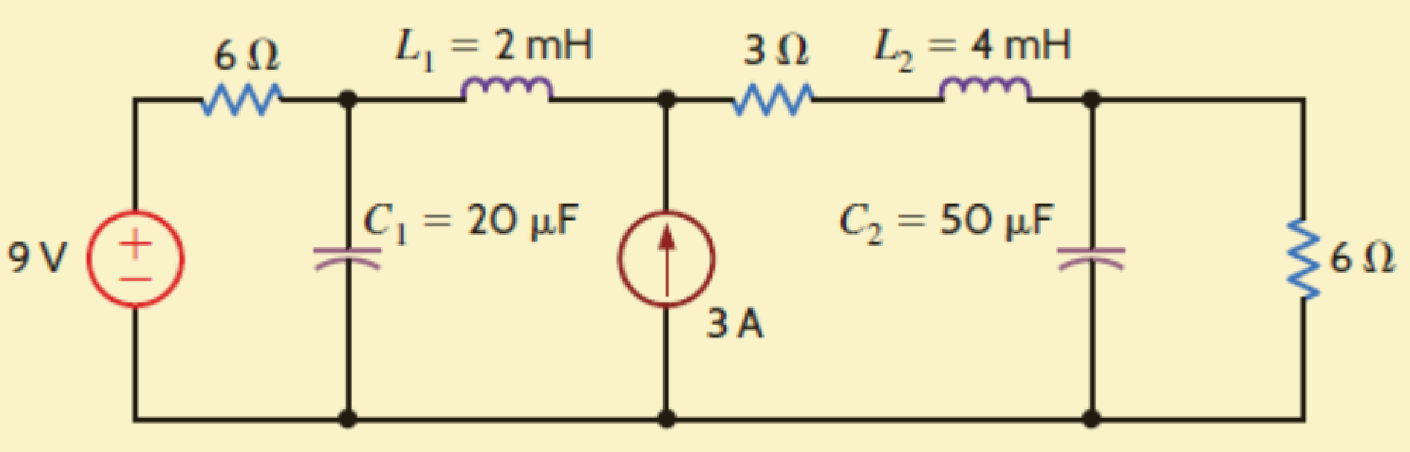
$$p(t) = L \cdot i(t) \frac{di(t)}{dt} = \begin{cases} 2 \cdot t \ W & \rightarrow t = [0:1] \\ -1m + 0.5 \cdot (t - 1m) \ W & \rightarrow t = [1:2] \\ 0 & \rightarrow t = [2:3] \\ -0.5m + 0.5 \cdot (t - 3m) \ W & \rightarrow t = [3:4] \end{cases}$$

$$w_L(t) = \frac{1}{2} L \cdot i(t)^2 = \begin{cases} t^2 \ J & \rightarrow t = [0:1] \\ 2.5 \cdot [30m - 10 \cdot t]^2 \ mJ & \rightarrow t = [1:2] \\ 250 \ nJ & \rightarrow t = [2:3] \\ 2.5 \cdot [40m - 10 \cdot t]^2 \ mJ & \rightarrow t = [3:4] \end{cases}$$

$$w_L(t = 1.5m) = 562 \ nJ$$

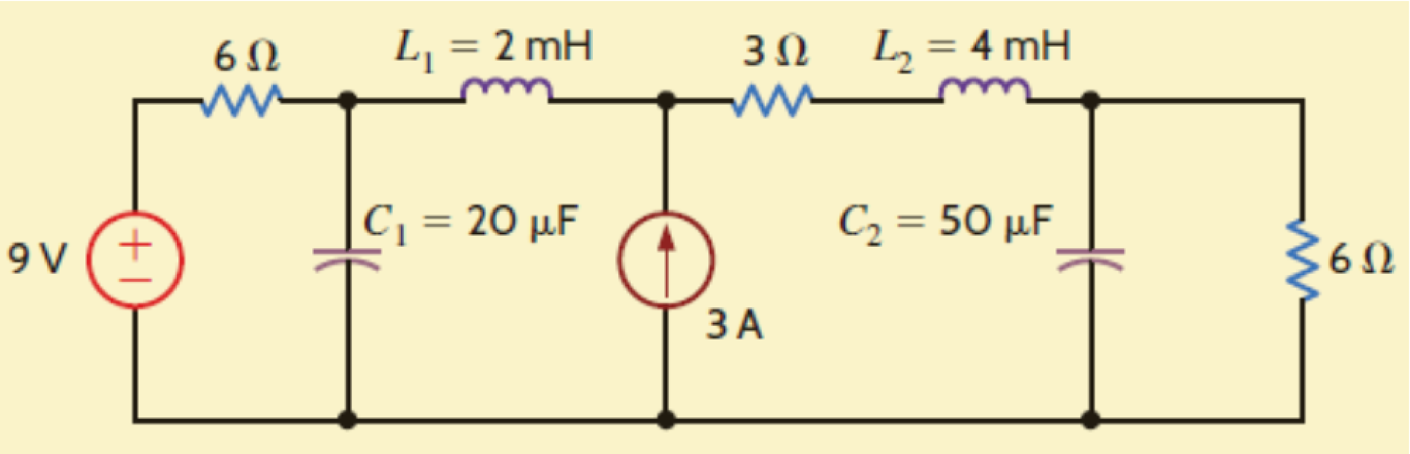
Example 6.5

Find the total energy stored in the circuit provided.

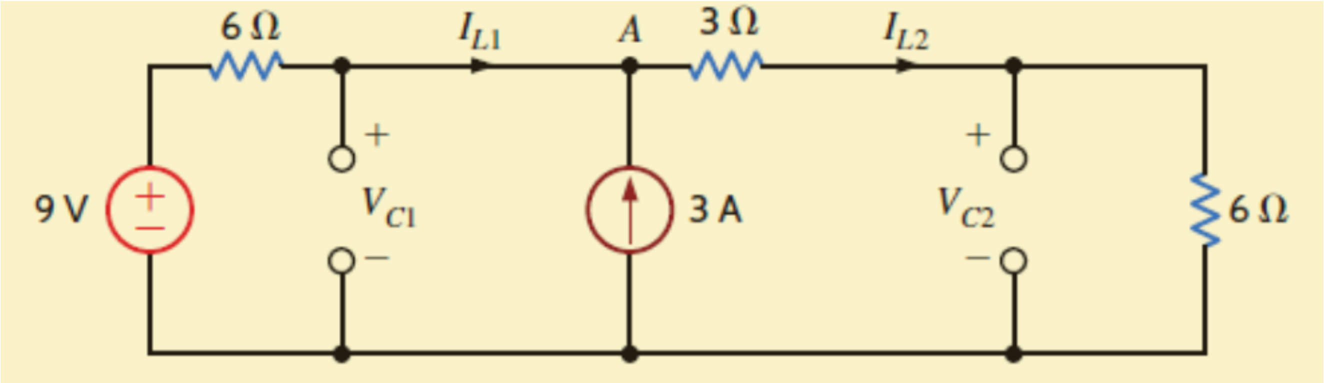


Example 6.5

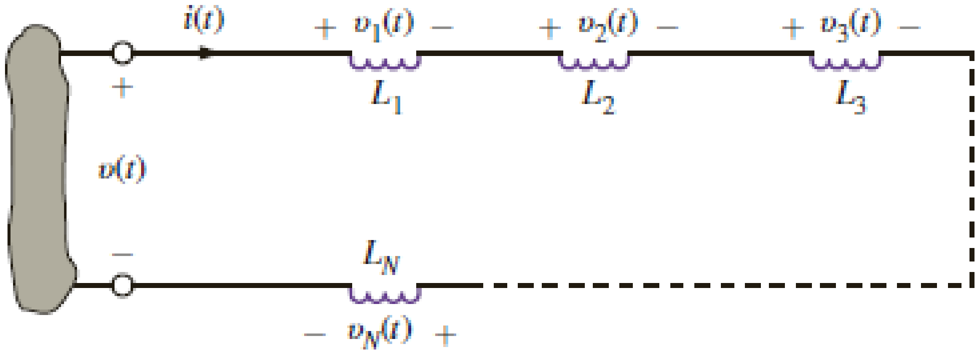
Find the total energy stored in the circuit provided.

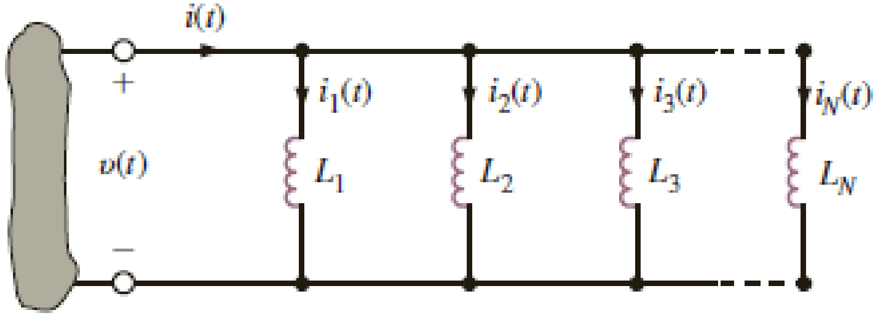


@ DC $V_L = 0$ & $I_C=0$
→ L = short circuit
→ C = open circuit

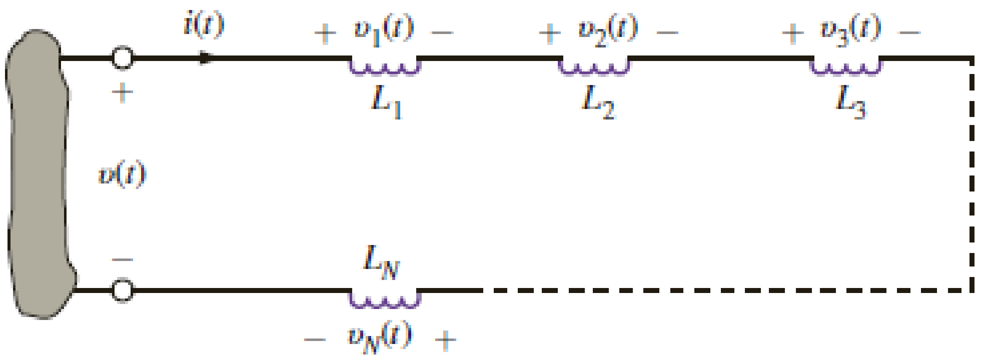


Series \ Parallel Inductors

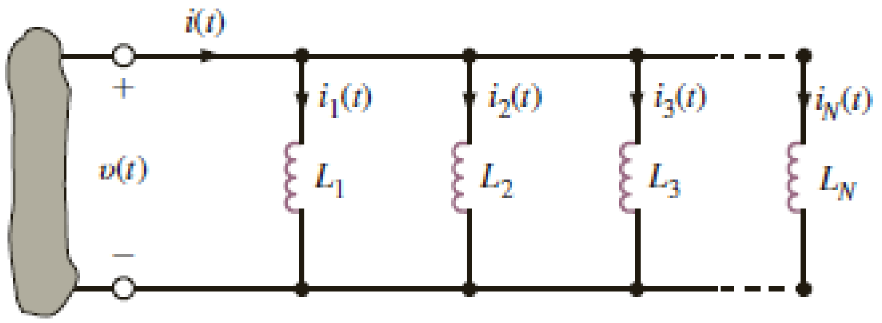




Series \ Parallel Inductors

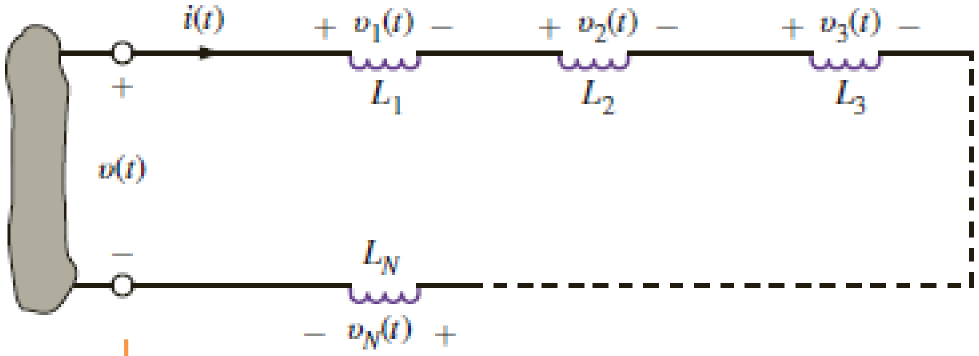


$$v(t) = v_1(t) + v_2(t) + \cdots + v_N(t)$$
$$= L_1 \frac{di(t)}{dt} + L_2 \frac{di(t)}{dt} + \cdots + L_N \frac{di(t)}{dt}$$
$$= [L_1 + L_2 + \cdots + L_N] \frac{di(t)}{dt}$$

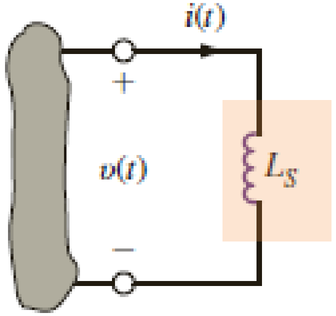


$$i(t) = i_1(t) + i_2(t) + \cdots +$$
$$= \frac{1}{L_1} v(t)dt + \frac{1}{L_2} v(t)dt + \cdots + \frac{1}{L_N} v(t)dt$$
$$= \left[\frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_N}\right] v(t)dt$$

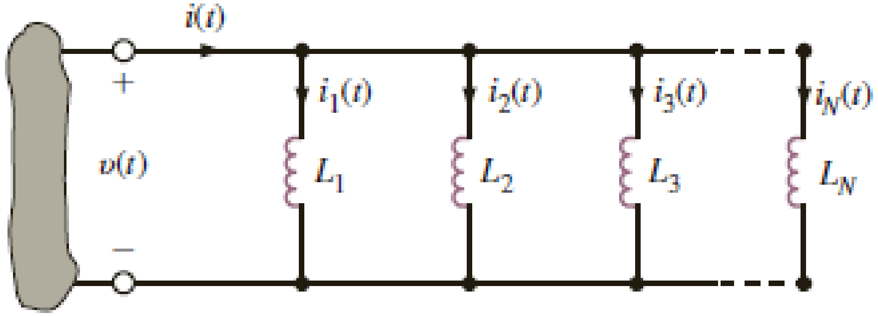
Series \ Parallel Inductors



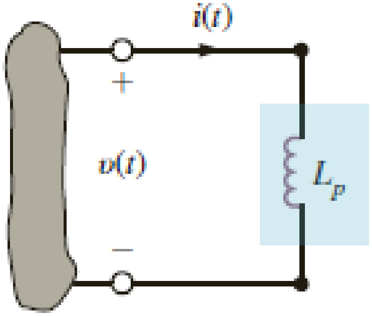
$$v(t) = v_1(t) + v_2(t) + \cdots + v_N(t)$$
$$= L_1 \frac{di(t)}{dt} + L_2 \frac{di(t)}{dt} + \cdots + L_N \frac{di(t)}{dt}$$
$$= [L_1 + L_2 + \cdots + L_N] \frac{di(t)}{dt}$$



$$L_s = L_1 + L_2 + \cdots + L_N$$

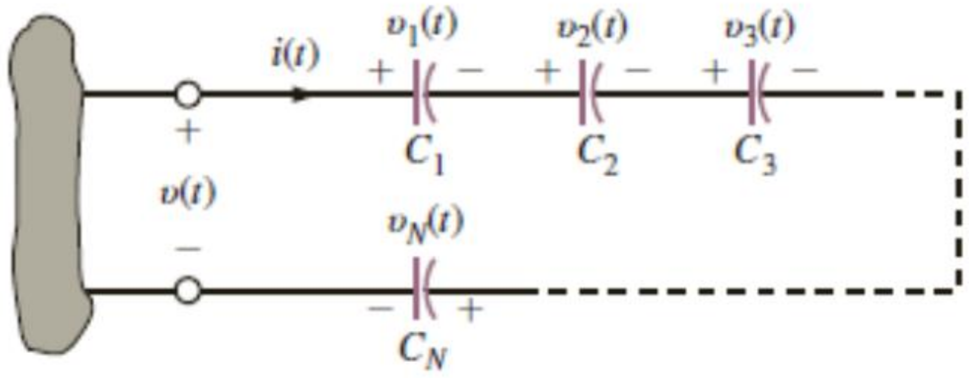


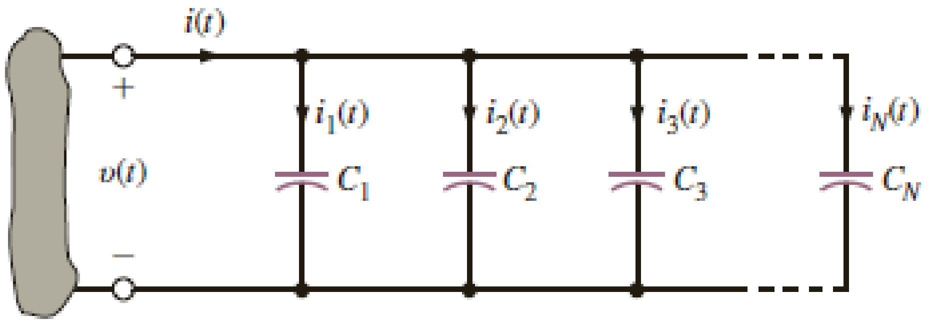
$$i(t) = i_1(t) + i_2(t) + \cdots +$$
$$= \frac{1}{L_1} v(t)dt + \frac{1}{L_2} v(t)dt + \cdots + \frac{1}{L_N} v(t)dt$$
$$= \left[\frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_N}\right] v(t)dt$$



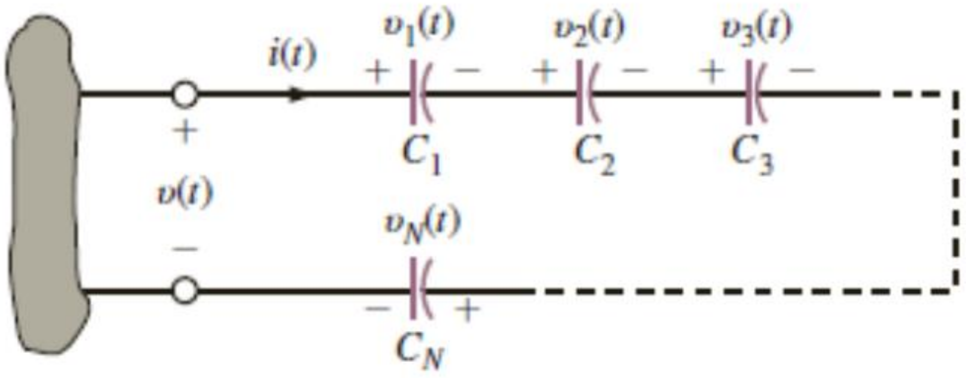
$$\frac{1}{L_p} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots + \frac{1}{L_N}$$

Series \ Parallel Capacitors





Series \ Parallel Capacitors



$$v(t) = v_1(t) + v_2(t) + \cdots + v_N(t)$$
$$= \frac{1}{C_1} i(t)dt + \frac{1}{C_2} i(t)dt + \cdots + \frac{1}{C_N} i(t)dt$$
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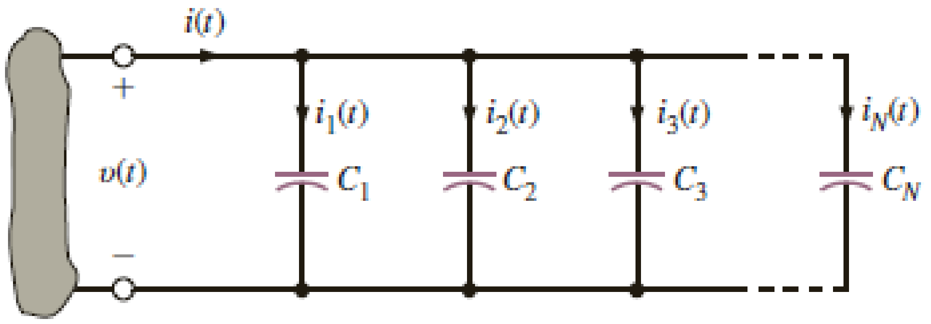

$$i(t) = i_1(t) + i_2(t) + \cdots + i_N$$
$$= C_1 \frac{dv(t)}{dt} + C_2 \frac{dv(t)}{dt} + \cdots + C_N \frac{dv(t)}{dt}$$
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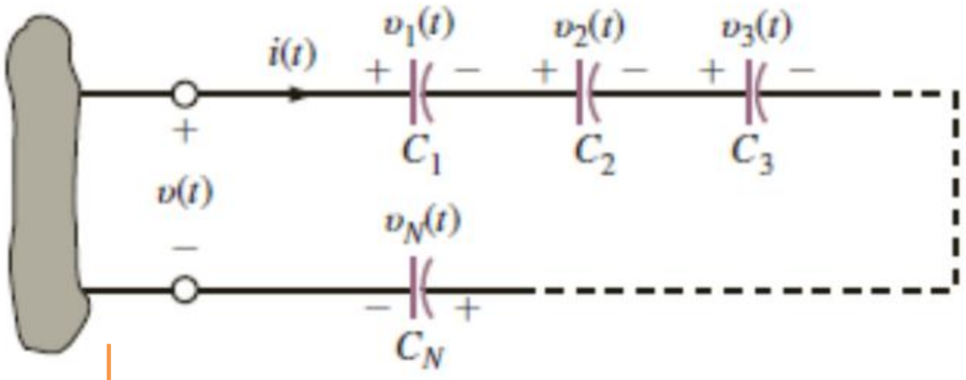
Series \ Parallel Capacitors



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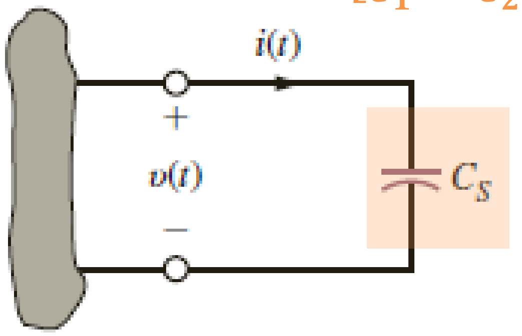
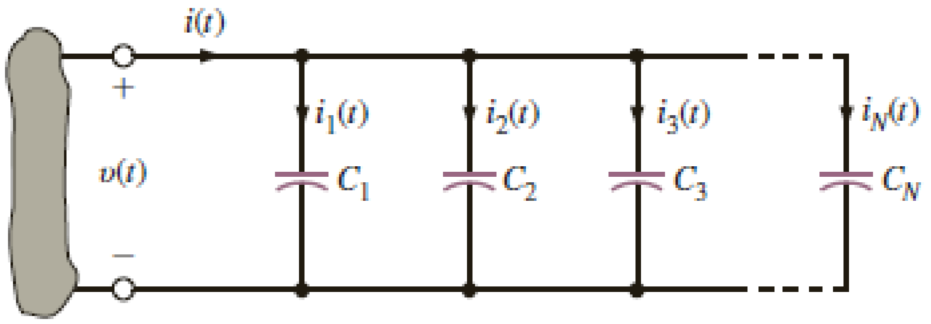


$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_N}$$



$$i(t) = i_1(t) + i_2(t) + \cdots + i_N$$
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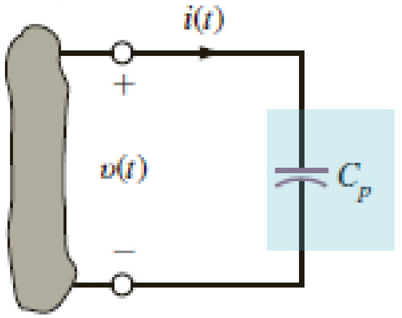
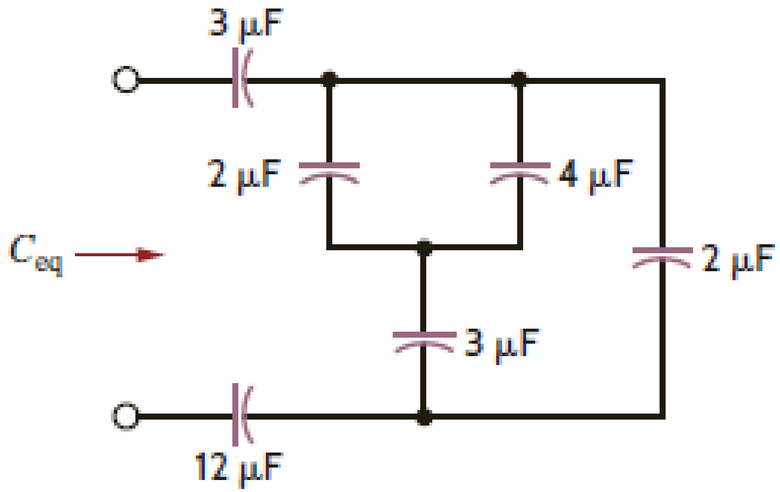


$$C_p = C_1 + C_2 + \cdots + C_N$$

Learning Assessment E6.12

Compute the equivalent capacitance of the network provided.



Learning Assessment E6.15

Find L_T in the network provided.