6.6 In Fig. 6.43, if \( i = \cos 4t \) and \( v = \sin 4t \), the element is:
(a) a resistor  (b) a capacitor  (c) an inductor

![Figure 6.43](image)

For Review Question 6.6.

6.7 A 5-H inductor changes its current by 3 A in 0.2 s. The voltage produced at the terminals of the inductor is:
(a) 75 V  (b) 8.888 V  
(c) 3 V  (d) 1.2 V

6.8 If the current through a 10-mH inductor increases from zero to 2 A, how much energy is stored in the inductor?
(a) 40 mJ  (b) 20 mJ  
(c) 10 mJ  (d) 5 mJ

6.9 Inductors in parallel can be combined just like resistors in parallel.
(a) True  (b) False

6.10 For the circuit in Fig. 6.44, the voltage divider formula is:
(a) \( v_1 = \frac{L_1 + L_2}{L_1} v_i \)  (b) \( v_1 = \frac{L_1 + L_2}{L_2} v_i \)
(c) \( v_1 = \frac{L_2}{L_1 + L_2} v_i \)  (d) \( v_1 = \frac{L_1}{L_1 + L_2} v_i \)

![Figure 6.44](image)

For Review Question 6.10.

Answers: 6.1a, 6.2d, 6.3d, 6.4b, 6.5c, 6.6b, 6.7a, 6.8, 6.9a, 6.10d.

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**Problems**

### Section 6.2 Capacitors

6.1 If the voltage across a 5-F capacitor is \( 2te^{-3t} \) V, find the current and the power.

6.2 A 20-\( \mu \)F capacitor has energy \( u(t) = 10 \cos^2 37\pi t \) J. Determine the current through the capacitor.

6.3 Design a problem to help other students better understand how capacitors work.

6.4 A current of 6 \( \sin 4t \) A flows through a 2-F capacitor. Find the voltage \( v(t) \) across the capacitor given that \( v(0) = 1 \) V.

6.5 The voltage across a 4-\( \mu \)F capacitor is shown in Fig. 6.45. Find the current waveform.

![Figure 6.45](image)

For Prob. 6.5.

6.6 The voltage waveform in Fig. 6.46 is applied across a 30-\( \mu \)F capacitor. Draw the current waveform through it.

![Figure 6.46](image)

For Prob. 6.6.

6.7 At \( t = 0 \), the voltage across a 50-mF capacitor is 11 V. Calculate the voltage across the capacitor for \( t > 0 \) when current \( 4t \) mA flows through it.

6.8 A 4-mF capacitor has the terminal voltage
\[
v = \begin{cases} 
50 \text{ V}, & t \leq 0 \\
Ae^{-100t} + Be^{-500t} \text{ V}, & t \geq 0
\end{cases}
\]
If the capacitor has an initial current of 2 A, find:
(a) the constants \( A \) and \( B \),
(b) the energy stored in the capacitor at \( t = 0 \),
(c) the capacitor current for \( t > 0 \).
6.33 Obtain the Thevenin equivalent at the terminals, $a$–$b$, of the circuit shown in Fig. 6.65. Please note that Thevenin equivalent circuits do not generally exist for circuits involving capacitors and resistors. This is a special case where the Thevenin equivalent circuit does exist.

![Figure 6.65](image)

For Prob. 6.33.

Section 6.4 Inductors

6.34 The current through a 10-mH inductor is $6e^{-t/2}$ A. Find the voltage and the power at $t = 3$ s.

6.35 An inductor has a linear change in current from 50 mA to 100 mA in 2 ms and induces a voltage of 160 mV. Calculate the value of the inductor.

6.36 Design a problem to help other students better understand how inductors work.

6.37 The current through a 12-mH inductor is $4 \sin 100t$ A. Find the voltage across the inductor for $0 < t < \pi/200$ s, and the energy stored at $t = \pi/100$ s.

6.38 The current through a 40-mH inductor is

$$i(t) = \begin{cases} 0, & t < 0 \\ te^{-2t} A, & t > 0 \end{cases}$$

Find the voltage $v(t)$.

6.39 The voltage across a 200-mH inductor is given by

$$v(t) = 3t^2 + 2t + 4 \text{ V}$$

for $t > 0$.

Determine the current $i(t)$ through the inductor. Assume that $i(0) = 1$ A.

6.40 The current through a 10-mH inductor is shown in Fig. 6.66. Determine the voltage across the inductor at $t = 1$, $3$, and $5$ ms.

![Figure 6.66](image)

For Prob. 6.40.

6.41 The voltage across a 2-H inductor is $20(1 - e^{-2t})$ V. If the initial current through the inductor is 0.3 A, find the current and the energy stored in the inductor at $t = 1$ s.

6.42 If the voltage waveform in Fig. 6.67 is applied across the terminals of a 10-H inductor, calculate the current through the inductor. Assume $i(0) = -1$ A.

![Figure 6.67](image)

For Prob. 6.42.

6.43 The current in an 80-mH inductor increases from 0 to 60 mA. How much energy is stored in the inductor?

6.44 A 100-mH inductor is connected in parallel with a 2-kΩ resistor. The current through the inductor is $i(t) = 50e^{-400t}$ mA. (a) Find the voltage $v_L$ across the inductor. (b) Find the voltage $v_R$ across the resistor. (c) Does $v_R(t) + v_L(t) = 0$? (d) Calculate the energy in the inductor at $t = 0$.

6.45 If the voltage waveform in Fig. 6.68 is applied to a 50-mH inductor, find the inductor current $i(t)$. Assume $i(0) = 0$.

![Figure 6.68](image)

For Prob. 6.45.

6.46 Find $v_C$, $i_L$, and the energy stored in the capacitor and inductor in the circuit of Fig. 6.69 under dc conditions.

![Figure 6.69](image)

For Prob. 6.46.
6.61 Consider the circuit in Fig. 6.83. Find: (a) \( I_{eq} \), \( i(t) \), and \( i_2(t) \) if \( i_1 = 3e^{-3t} \) mA, (b) \( V_{dc} \), (c) energy stored in the 20-mH inductor at \( t = 1 \) s.

![Figure 6.83](image)

For Prob. 6.61.

6.62 Consider the circuit in Fig. 6.84. Given that \( v(t) = 12e^{-3t} \) mV for \( t > 0 \) and \( i(0) = -10 \) mA, find: (a) \( i_2(0) \), (b) \( i_1(t) \) and \( i_2(t) \).

![Figure 6.84](image)

For Prob. 6.62.

6.63 In the circuit of Fig. 6.85, sketch \( v_o \).

![Figure 6.85](image)

For Prob. 6.63.

6.64 The switch in Fig. 6.86 has been in position \( A \) for a long time. At \( t = 0 \), the switch moves from position \( A \) to \( B \). The switch is a make-before-break type so that there is no interruption in the inductor current. Find: (a) \( i(t) \) for \( t < 0 \), (b) \( v \) just after the switch has been moved to position \( B \), (c) \( v(t) \) long after the switch is in position \( B \).

![Figure 6.86](image)

For Prob. 6.64.

6.65 The inductors in Fig. 6.87 are initially charged and are connected to the black box at \( t = 0 \). If \( i_1(0) = 4 \) A, \( i_2(0) = -2 \) A, and \( v(t) = 50e^{-2t} \) mV, \( t \geq 0 \), find:

- (a) the energy initially stored in each inductor,
- (b) the total energy delivered to the black box from \( t = 0 \) to \( t = \infty \),
- (c) \( i_1(t) \) and \( i_2(t) \), \( t \geq 0 \),
- (d) \( i(t) \), \( t \geq 0 \).

![Figure 6.87](image)

For Prob. 6.65.

6.66 The current \( i(t) \) through a 40-mH inductor is equal, in magnitude, to the voltage across it for all values of time. If \( i(0) = 5 \) A, find \( i(t) \).

Section 6.6 Applications

6.67 An op amp integrator has \( R = 100 \) kΩ and \( C = 0.01 \) µF. If the input voltage is \( v_i = 10 \sin 50t \) mV, obtain the output voltage.
6.68 A 10-V dc voltage is applied to an integrator with \( R = 50 \text{ k}\Omega \), \( C = 100 \mu\text{F} \) at \( t = 0 \). How long will it take for the op amp to saturate if the saturation voltages are +12 V and -12 V? Assume that the initial capacitor voltage was zero.

6.69 An op amp integrator with \( R = 4 \text{ M}\Omega \) and \( C = 1 \mu\text{F} \) has the input waveform shown in Fig. 6.88. Plot the output waveform.

![Figure 6.88](image)

*Figure 6.88*
For Prob. 6.69.

6.70 Using a single op amp, a capacitor, and resistors of \( 100 \text{ k}\Omega \) or less, design a circuit to implement

\[
v_o = -50 \int_0^t v_i(t) \, dt
\]

Assume \( v_o = 0 \) at \( t = 0 \).

6.71 Show how you would use a single op amp to generate

\[
v_o = -\int_0^t (v_1 + 4v_2 + 10v_3) \, dt
\]

If the integrating capacitor is \( C = 2 \mu\text{F} \), obtain the other component values.

6.72 At \( t = 1.5 \text{ ms} \), calculate \( v_o \) due to the cascaded integrators in Fig. 6.89. Assume that the integrators are reset to 0 V at \( t = 0 \).

![Figure 6.89](image)

*Figure 6.89*
For Prob. 6.72.

6.73 Show that the circuit in Fig. 6.90 is a noninverting integrator.

![Figure 6.90](image)

*Figure 6.90*
For Prob. 6.73.

6.74 The triangular waveform in Fig. 6.91(a) is applied to the input of the op amp differentiator in Fig. 6.91(b). Plot the output.

![Figure 6.91](image)

*Figure 6.91*
For Prob. 6.74.

6.75 An op amp differentiator has \( R = 250 \text{ k}\Omega \) and \( C = 10 \mu\text{F} \). The input voltage is a ramp \( r(t) = 12t \text{ mV} \). Find the output voltage.

6.76 A voltage waveform has the following characteristics: a positive slope of 20 V/s for 5 ms followed by a negative slope of 10 V/s for 10 ms. If the waveform is applied to a differentiator with \( R = 50 \text{ k}\Omega \), \( C = 10 \mu\text{F} \), sketch the output voltage waveform.
7.4 The switch in Fig. 7.84 has been in position A for a long time. Assume the switch moves instantaneously from A to B at \( t = 0 \). Find \( v \) for \( t > 0 \).

**Figure 7.84**
For Prob. 7.4.

7.5 Using Fig. 7.85, design a problem to help other students understand source-free RC circuits.

**Figure 7.85**
For Prob. 7.5.

7.6 The switch in Fig. 7.86 has been closed for a long time, and it opens at \( t = 0 \). Find \( v(t) \) for \( t \geq 0 \).

**Figure 7.86**
For Prob. 7.6.

7.7 Assuming that the switch in Fig. 7.87 has been in position A for a long time and is moved to position B at \( t = 0 \), find \( v_c(t) \) for \( t > 0 \).

**Figure 7.87**
For Prob. 7.7.

7.8 For the circuit in Fig. 7.88, if
\[
\nu = 10e^{-4t} \text{ V} \quad \text{and} \quad i = 0.2 e^{-4t} \text{ A}, \quad t > 0
\]

(a) Find \( R \) and \( C \).

(b) Determine the time constant.

(c) Calculate the initial energy in the capacitor.

(d) Obtain the time it takes to dissipate 50 percent of the initial energy.

**Figure 7.88**
For Prob. 7.8.

7.9 The switch in Fig. 7.89 opens at \( t = 0 \). Find \( v_c \) for \( t > 0 \).

**Figure 7.89**
For Prob. 7.9.

7.10 For the circuit in Fig. 7.90, find \( v_a(t) \) for \( t > 0 \).

Determine the time necessary for the capacitor voltage to decay to one-third of its value at \( t = 0 \).

**Figure 7.90**
For Prob. 7.10.

Section 7.3 The Source-Free RL Circuit

7.11 For the circuit in Fig. 7.91, find \( i_o \) for \( t > 0 \).

**Figure 7.91**
For Prob. 7.11.
For the circuit in Fig. 7.100,
\[ v = 150e^{-50t} \text{ V} \]
and
\[ i = 30e^{-50t} \text{ A}, \quad t > 0 \]
(a) Find L and R.
(b) Determine the time constant.
(c) Calculate the initial energy in the inductor.
(d) What fraction of the initial energy is dissipated in 10 ms?

**Figure 7.100**
For Prob. 7.20.

In the circuit of Fig. 7.101, find the value of R for which the steady-state energy stored in the inductor will be 0.25 J.

**Figure 7.101**
For Prob. 7.21.

Find \( i(t) \) and \( v(t) \) for \( t > 0 \) in the circuit of Fig. 7.102 if \( i(0) = 20 \text{ A} \).

**Figure 7.102**
For Prob. 7.22.

Consider the circuit in Fig. 7.103. Given that \( v_a(0) = 2 \text{ V} \), find \( v_a \) and \( v_x \) for \( t > 0 \).

**Figure 7.103**
For Prob. 7.23.

### Section 7.4 Singularity Functions

7.24 Express the following signals in terms of singularity functions.

(a) \( v(t) = \begin{cases} 0, & t < 0 \\ -5, & t > 0 \end{cases} \)

(b) \( i(t) = \begin{cases} 0, & t < 1 \\ -10, & 1 < t < 3 \\ 10, & 3 < t < 5 \\ 0, & t > 5 \end{cases} \)

(c) \( x(t) = \begin{cases} t - 1, & 1 < t < 2 \\ 1, & 2 < t < 3 \\ 4 - t, & 3 < t < 4 \\ 0, & \text{ Otherwise} \end{cases} \)

(d) \( y(t) = \begin{cases} 2, & t < 0 \\ -5, & 0 < t < 1 \\ 0, & t > 1 \end{cases} \)

7.25 Design a problem to help other students better understand singularity functions.

7.26 Express the signals in Fig. 7.104 in terms of singularity functions.

**Figure 7.104**
For Prob. 7.26.

7.27 Express \( v(t) \) in Fig. 7.105 in terms of step functions.
7.44 The switch in Fig. 7.111 has been in position a for a long time. At \( t = 0 \), it moves to position b. Calculate \( i(t) \) for all \( t > 0 \).

![Figure 7.111](image)

For Prob. 7.44.

7.45 Find \( v_o \) in the circuit of Fig. 7.112 when \( v_i = 6u(t) \). Assume that \( v_o(0) = 1 \text{ V} \).

![Figure 7.112](image)

For Prob. 7.45.

7.46 For the circuit in Fig. 7.113, \( i_S(t) = 5u(t) \). Find \( v(t) \).

![Figure 7.113](image)

For Prob. 7.46.

7.47 Determine \( v(t) \) for \( t > 0 \) in the circuit of Fig. 7.114 if \( v(0) = 0 \).

![Figure 7.114](image)

For Prob. 7.47.
7.55 Find \( v(t) \) for \( t < 0 \) and \( t > 0 \) in the circuit of Fig. 7.121.

![Fig. 7.121](image)

For Prob. 7.55.

7.56 For the network shown in Fig. 7.122, find \( v(t) \) for \( t > 0 \).

![Fig. 7.122](image)

For Prob. 7.56.

*7.57 Find \( i_1(t) \) and \( i_2(t) \) for \( t > 0 \) in the circuit of Fig. 7.123.

![Fig. 7.123](image)

For Prob. 7.57.

7.58 Rework Prob. 7.17 if \( i(0) = 10 \text{ A} \) and \( v(t) = 20u(t) \text{ V} \).

7.59 Determine the step response \( u_d(t) \) to \( v_s = 9u(t) \text{ V} \) in the circuit of Fig. 7.124.

![Fig. 7.124](image)

For Prob. 7.59.

7.60 Find \( v(t) \) for \( t > 0 \) in the circuit of Fig. 7.125 if the initial current in the inductor is zero.

![Fig. 7.125](image)

For Prob. 7.60.

7.61 In the circuit of Fig. 7.126, \( i_s \) changes from 5 A to 10 A at \( t = 0 \); that is, \( i_s = (5 + 5u(t)) \text{ A} \). Find \( v \) and \( i \).

![Fig. 7.126](image)

For Prob. 7.61.

7.62 For the circuit in Fig. 7.127, calculate \( i(t) \) if \( i(0) = 0 \).

![Fig. 7.127](image)

For Prob. 7.62.

7.63 Obtain \( v(t) \) and \( i(t) \) in the circuit of Fig. 7.128.

![Fig. 7.128](image)

For Prob. 7.63.

7.64 Find \( v_o(t) \) for \( t > 0 \) in the circuit of Fig. 7.129.

![Fig. 7.129](image)

For Prob. 7.64.
7.65 If the input pulse in Fig. 7.130(a) is applied to the circuit in Fig. 7.130(b), determine the response \( i(t) \).

**Figure 7.130**
For Prob. 7.65.

Section 7.7 First-order Op Amp Circuits

7.66 Using Fig. 7.131, design a problem to help other students better understand first-order op amp circuits.

**Figure 7.131**
For Prob. 7.66.

7.67 If \( v(0) = 10 \) V, find \( v_o(t) \) for \( t > 0 \) in the op amp circuit of Fig. 7.132. Let \( R = 10 \) k\( \Omega \) and \( C = 1 \) \( \mu \)F.

**Figure 7.132**
For Prob. 7.67.

7.68 Obtain \( v_o \) for \( t > 0 \) in the circuit of Fig. 7.133.

**Figure 7.133**
For Prob. 7.68.

7.69 For the op amp circuit in Fig. 7.134, find \( v_o(t) \) for \( t > 0 \).

**Figure 7.134**
For Prob. 7.69.

7.70 Determine \( v_o \) for \( t > 0 \) when \( v_s = 20 \) mV in the op amp circuit of Fig. 7.135.

**Figure 7.135**
For Prob. 7.70.

7.71 For the op amp circuit in Fig. 7.136, suppose \( v_o = 0 \) and \( v_s = 3 \) V. Find \( v(t) \) for \( t > 0 \).

**Figure 7.136**
For Prob. 7.71.
7.72 Find $i_c$ in the op amp circuit in Fig. 7.137. Assume that $v(0) = -2 \text{ V}$, $R = 10 \text{ k}\Omega$, and $C = 10 \mu\text{F}$.

![Figure 7.137](image)

For Prob. 7.72.

7.73 (Diagram)

For the circuit shown in Fig. 7.138, solve for $i_0(t)$.

![Figure 7.138](image)

For Prob. 7.73.

7.74 Determine $v_o(t)$ for $t > 0$ in the circuit of Fig. 7.139. Let $i_s = 10u(t) \mu\text{A}$ and assume that the capacitor is initially uncharged.

![Figure 7.139](image)

For Prob. 7.74.

7.75 In the circuit of Fig. 7.140, find $v_o$ and $i_o$, given that $v_s = 4u(t) \text{ V}$ and $v(0) = 1 \text{ V}$.

![Figure 7.140](image)

For Prob. 7.75.

7.76 Repeat Prob. 7.49 using PSpice. 

7.77 The switch in Fig. 7.141 opens at $t = 0$. Use PSpice to determine $v(t)$ for $t > 0$.

![Figure 7.141](image)

For Prob. 7.77.

7.78 The switch in Fig. 7.142 moves from position $a$ to $b$ at $t = 0$. Use PSpice to find $i(t)$ for $t > 0$.

![Figure 7.142](image)

For Prob. 7.78.

7.79 In the circuit of Fig. 7.143, the switch has been in position $a$ for a long time but moves instantaneously to position $b$ at $t = 0$. Determine $i_o(t)$.

![Figure 7.143](image)

For Prob. 7.79.

7.80 In the circuit of Fig. 7.144, assume that the switch has been in position $a$ for a long time, find:

(a) $i_1(0)$, $i_2(0)$, and $v_o(0)$

(b) $i_1(t)$

(c) $i_1(\infty)$, $i_2(\infty)$, and $v_o(\infty)$.